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CONTENTS

PAGE

FIELD GRADING RED TART CHERRIES.....By H. P. Gaston and J. H. Levin 343

SUDANGRASS VARIETIES FOR MICHIGAN.....By Milo B. Tesar 350

CONTROLLING ALDER WITH BASAL STEM SPRAYS.....By Maurice W. Day 354

SEED TREATMENT STUDIES FOR DAMPING-OFF CONTROL IN GARDEN AND CANNING BEANS (REPORT OF PROGRESS).....By Axel L. Andersen and Donald J. deZeeuw 357

UREA-NITROGEN APPLIED TO THE LEAVES OF CERTAIN VEGETABLE CROPS.....By B. D. Mayberry and S. H. Wittwer 365

ANNUAL ORCHARD COVER CROP TESTS IN MICHIGAN.....By Walter Toenjes 370

PROGRESS REPORT ON THE WOODED WATERSHED OF THE MICHIGAN HYDROLOGIC RESEARCH STATION.....By James L. Smith and George A. Crabb, Jr. 383

(Continued on Next Page)

MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
EAST LANSING

THE QUARTERLY BULLETIN

The Quarterly Bulletin of the Michigan Agricultural Experiment Station is issued in February, May, August and November. It presents progress reports on long-term major research projects and final reports on short-term projects.

CONTENTS

(Continued from Outside Front Cover)

PAGE

A Standardized Pressure Test for Moisture in Grass-silage Making.....*By S. T. Dexter* 395

Improvement of Potato Chip Color by Hot Water Treatment of Slices.....*By S. T. Dexter and D. K. Salunkhe* 399

A Double-counter Rotating-head Mechanical Sugar Beet Thinner.....*By George W. French* 403

Comparative Tillage Tests at East Lansing, Michigan (A Progress Report) .....*By James Tyson and George A. Crabb, Jr.* 412

The Correlation of Laboratory Screening of Turf Fungicides with Field Results.....*By William Klomparens and John R. Vaughn* 425

Mint Rust and Its Control.....*By Ray Nelson* 436

Potential Michigan Public School Enrollments.....*By John F. Thaden and C. L. Taylor* 456

Diagnostic Techniques Used In Soil Fertility Studies.....*By K. Lawton, L. S. Robertson, R. L. Cook and P. J. Rood* 466

Journal Article Abstracts..... 472

THE QUARTERLY BULLETIN

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MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
EAST LANSING

C. M. HARDIN, DIRECTOR
R. E. MARSHALL, ASSISTANT DIRECTOR
J. G. DUNCAN, EDITOR

FIELD GRADING RED TART CHERRIES[1]

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U. S. DEPARTMENT OF AGRICULTURE

THE PROBLEM

RECENTLY completed surveys, made by the Michigan Cooperative Crop Reporting Service, show that during the next 5 years Michigan cherry production can be expected to increase by at least 25 percent. There is also an upward trend in the tonnage grown in competing areas, some of which are closer than Michigan to important eastern markets. If these predicted increases materialize it will become increasingly difficult to sell Michigan cherries at prices that will return a profit to both growers and packers.

Producers are contributing considerable sums of money to a program designed to promote the sale of cherries. Authorities agree that if maximum benefits are to be realized from this work, grade A cherries must be made available to consumers. There is no substitute for excellence; and the problems of increased production and more determined competition can be solved only if Michigan puts up a pack of high quality.

The Michigan cherry industry has come to realize that to accomplish this end will require the active cooperation of both growers and processors. After making a thorough study of the problem, a representative group, made up of both producers and packers, concluded that the most practical way to improve the quality of the Michigan pack was to bring about the enactment of legislation making it illegal for growers to sell, and for processors to buy, lots of cherries of which more than 12 percent are defective. The legislation recommended by this group was enacted January 16, 1952.

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[1]A report of a study made under the Research and Marketing Act of 1946. Departments of Horticulture and Agricultural Engineering, Michigan Agricultural Experiment Station and Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A., Cooperating.

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ARTICLE 34-40

THE REGULATION

MICHIGAN STATE DEPARTMENT OF AGRICULTURE REGULATION NO. 527

1. U. S. Standards for red sour cherries for manufacture, hereby defined as canning and/or preserving, must meet the standards for U. S. No. 1 grade, except that each cherry shall have a diameter of not less than 9/16 of one inch. Also a total tolerance of 12 percent by weight shall be permitted for grade defects, but no part of this tolerance shall be allowed for cherries which are affected by worms.

2. No red sour cherries shall be offered for sale or sold for canning and/or preserving that do not meet the grade established in Paragraph No. 1.

3. Every lot of red sour cherries sold for canning and/or preserving must be accompanied by a Federal-State inspection certificate showing the grade of the cherries to be equal to the grade established in Paragraph No. 1.

THE SOLUTION

It is impracticable for processors to sort out more than 5 percent of the cherries that pass through their packing lines. One alternative is to decrease the speed of processing lines. Doing so, however, materially reduces efficiency and increases costs. Diminishing the rate at which the fruit is processed not only increases costs of production but also decreases the volume of fruit that can be packed in a given time. This may make it impossible for processors to accept the fruit as rapidly as growers would like to deliver it. Delays of this nature are likely to disrupt picking schedules and may even mean the total loss of a part of the crop. This means that if packers are to put up an A grade cherry, producers must supply them with fruit of which at least 88 percent is without defects.

The most practical way for growers to accomplish this is to "field grade" inferior cherries before they leave the farm.

A GOOD SYSTEM OF FIELD GRADING SHOULD:

1. **Be inexpensive.**

2. **Require a minimum of equipment.**

3. **Involve a minimum amount of handling.** Handling causes bruises and lowers quality, thereby defeating the purpose of doing the work.

4. **Make it possible to do the work quickly.**

5. **Be flexible.** Under unfavorable conditions such as those that are likely to prevail after a wind storm, considerable grading may be necessary. When conditions are favorable a minimum amount will be required. A good system of grading makes it easy to increase or reduce the size of the sorting crew as occasion demands.

6. **Make it possible to check the effectiveness of the work done by individual pickers.** Considerable damage is often done by pickers who squeeze or bruise the fruit and include stems, leaves and defective cherries. Any method that enables the foreman to identify such workers is desirable.

7. **Enable the grading crew to handle hot, sticky cherries with a minimum of damage.**

THE "PAIL METHOD" OF GRADING

An effective method of field grading has been devised. In this report it is referred to as the "pail method." This system of field grading has been practiced successfully by a small percentage of producers for many years. If a considerable percentage of the growers in Michigan will use this, or some other effective method of field grading, the quality of the Michigan cherry pack undoubtedly will be materially improved.

During the 1951 harvest season some experimental studies of this and other sorting methods were conducted. The results obtained indicate that the pail method has all of the advantages outlined above. There is good reason to believe that it can be used successfully by all Michigan cherry growers.

EQUIPMENT

Pail grading does not necessitate the purchase of special equipment. It does, however, require a somewhat greater number of pails than might otherwise be necessary. Approximately four pails are needed for each picker.

Some growers perforate the bottoms of their cherry pails to reduce the likelihood of their being carried away and used for other purposes.

PROCEDURE

When the pail method of grading is used the cherries are picked in the usual manner. When a picker has filled two pails he checks

them in at the grading station, which is located in a shady spot at or near the center of the picking area.

The picker receives credit[4] for the cherries and is given two empty pails.

After the cherries have been checked in, a sorter picks up a pail of the fruit and pours a thin layer onto the bottoms of two or more lugs that have been placed side by side. He then picks out the defective fruit in the layer before him. Another thin layer is poured onto those already in the lugs and the undergrade cherries are removed from this layer. This procedure is repeated until the lugs have been filled. Empty lugs are then placed on top of those containing graded cherries, and the sorting operation is continued as before. When the stack of lugs becomes too high for the sorter to work efficiently, he starts a new one.

In performing the grading operation the sorters see all of the fruit harvested by the individual pickers. Those who are doing poor work should be corrected. One effective method of accomplishing this end is to require the picker himself to sort the fruit before it is accepted.

The grading operation can be performed on the ground. Doing so, however, means that the sorted cherries must be loaded onto a truck or trailer before they can be moved out of the orchard. If the work is done on a truck or orchard trailer, as it was in the trials, this unnecessary handling operation is eliminated.

When the trees adjacent to a given station have been picked, the checker and sorters move to the next location.

LABOR REQUIREMENTS

The cherries have to be checked in and the picker credited with the amount harvested whether the fruit is field-graded or not. When cherries are pail-graded, the only workers required, in addition to those who check and handle the fruit, are the sorters.

The grading trials conducted in 1951 showed that a capable sorter can throw out enough defective cherries to raise the amount of grade A fruit by 5 percent while handling the cherries at the rate of 300 to 400 pounds per hour. Under favorable conditions two sorters can grade 4 tons of cherries in a 10-hour day.

[4]The credit may be in the form of tickets or the count may be punched on a suitable card. The picker is paid on the basis of the number of full pails delivered. Some growers may prefer to weigh the fruit and pay on the basis of the number of pounds delivered. Doing so, however, means that the grower must provide scales and some additional help.

A wind storm or other unfavorable circumstances may make it necessary to increase the number of sorters required to bring the fruit up to the desired grade.

Sorting can be done by almost anyone who has good eyesight and is cooperative and who possesses a fair amount of manual dexterity. In most picking crews are several workers who not only have these qualifications but who would rather sort than pick.

COSTS

The only equipment necessary to do pail grading is a liberal supply of pails. Inasmuch as the containers last for several years the investment, per ton of cherries handled in a given year, is relatively small.

The only other cost is the amount paid to the sorters. As previously stated a sorter can, under normal conditions, grade approximately 400 pounds of cherries per hour. If we assume that the workers are paid 75 cents per hour (as they were during the experiments conducted in 1951) the cost will be about $3.75 per ton.

When processors pay a premium for fruit of high quality, field grading increases grower income. The additional returns will pay a part or all of the cost involved. In some instances pail grading may actually increase net returns.

Growers who sell to processors who do not pay a premium for high quality must assume the cost of grading. In doing so they should remember that while they may not receive a direct payment for doing the work they will nevertheless share, indirectly at least, in the very real benefits which result from improving the quality of the pack.

IN PRACTICE

The pail method of sorting is an effective way of improving the grade of cherries. During the early part of the season, 90 percent or more of the cherries that came from the orchard where the grading trials were conducted were without defects and were graded U.S. No. 1. Toward the end of the season, however, the crew was moved to a block of trees in which much of the fruit had been damaged by wind. Only 86 percent of the first load of cherries picked in this area were graded U.S. No. 1. The grower was warned that loads of which 15 percent of the fruit was defective could not be accepted. Observations of the unharvested cherries led to the conclusion that unless the fruit was field graded, very few of the loads remaining in this block would grade above 86 percent perfect fruit, and it was feared that some of them might even fall below 85 per cent.

The 17 tons of cherries that remained on the trees were field graded by the pail method. Sorting raised the amount of perfect fruit to 90 percent or above. The average cost of doing the work was less than $5 per ton.

OTHER METHODS OF RAISING THE GRADE

MOVE CHERRIES TO PROCESSORS WITHOUT DELAY

Fruit deteriorates rapidly after being picked. Harvested cherries that are allowed to stand in the sun for even a few hours before delivery to processors are almost sure to grade out several points lower than they would have had they been held in the shade or handled more rapidly. The fruit should, of course, be protected during transit as well as while it is in the orchard.

Graded as well as unsorted fruit is subject to damage of this sort. Undoubtedly many Michigan growers could retain most of the natural quality possessed by the fruit as it hangs on the tree by merely protecting the harvested fruit from sun, wind and dust, and moving it to processors without delay.

CLOSE SUPERVISION OF PICKERS

The grade of cherries can be improved by close supervision of the pickers. This entails pouring over and examining the fruit contained in pails or lugs chosen at random, and thereby checking the nature of the work being done. This method is most effective when a small crew is directed by the owner or a competent and conscientious foreman.

If this system is to raise the grade materially it is usually necessary to make an incentive payment. Some growers pay a bonus of 5 cents per lug or about $4 per ton on all of the loads that grade 95 percent or more of perfect fruit.

Although this system has merit it does not provide a continuous check (as does the pail method) on the work of individual pickers, nor the opportunity to throw out the defective cherries that get into the pails.

USE OF AN INCLINED TABLE

The writers sorted cherries on a portable inclined table covered with white oilcloth. Although this method made it possible to remove defective fruit, it had certain disadvantages. It was found that the table soon became so sticky that the cherries would not roll. When this happened it was necessary to push them along by hand or with a

wooden paddle. This caused considerable mechanical injury. The labor cost was higher than that of pail grading, and the results obtained were less satisfactory.

USE OF A MOVING BELT

In processing plants, cherries are graded on moving belts. This system has been tried in a few Michigan orchards. Equipment, however, is usually rather expensive. If the belt is driven by an electric motor it must be located close to a source of power. If the cherries are poured into lugs before they are moved, taking the fruit to a stationary grader of this kind means extra handling which takes time, costs money and injures the fruit. The cherries can be moved to a stationary grader in the pails in which they are picked. When this system is employed, however, it is usually necessary to provide more than four pails per picker, and doing so adds to the expense of the operation.

A sorting belt powered by a gasoline engine can be moved through the orchard, but such a device has most of the disadvantages of the stationary units. Although a sorting belt at or in the orchard makes it possible to remove the defective fruit, most of the growers who do such field grading consider it less satisfactory than the pail method.

LUG TO LUG

Growers who do not have a sufficient number of picking buckets to use the pail method sometimes sort the fruit as it is poured from lug to lug. This method has some of the advantages of pail sorting, but it involves pouring the cherries over an extra time and may result in more bruising. Since the lugs are heavy and relatively hard to handle, the work is harder; and some spillage is almost inevitable. The results are, therefore, not likely to be entirely satisfactory.

CONCLUSIONS

1. Field grading is a proven method of improving the grade. It is relatively simple, effective and inexpensive.
2. Field grading benefits the grower, processor and consumer.
3. The pail method is a practical system of field grading.
4. The efficient use of the pail method should enable Michigan growers to improve the quality of the pack and thereby help to assure the future of the Michigan cherry industry.

SUDANGRASS VARIETIES FOR MICHIGAN

By MILO B. TESAR
DEPARTMENT OF FARM CROPS

SUDANGRASS grown on fertile soil is the best emergency pasture crop for the southern half of the lower peninsula of Michigan. Most of the acreage was planted to Common Sudangrass until recently; now a large acreage is planted to Sweet Sudangrass, a new variety. The experimental work reported here shows the relative yields and characteristics of this new variety as compared with those of two other new varieties and Common Sudangrass.

The new varieties tested were Tift, Sweet, and Piper Sudangrass released, respectively, by Agricultural Experiment Stations in Georgia in 1936, Texas in 1943, and Wisconsin in 1951. All three varieties were developed for resistance to leaf diseases to which Common Sudangrass is susceptible. Sweet Sudangrass is somewhat juicier and sweeter than the other varieties. One of the primary objectives in developing Piper was to obtain a Sudangrass with a lower hydrocyanic acid (HCN) content. At maturity, the seeds are chocolate-colored in Tift, reddish-black in Piper, and orange-red in Sweet Sudangrass in contrast to the light straw color of Common Sudangrass seed..

MATERIALS AND METHODS

Tift, Sweet, Piper, and Common Sudangrass were tested at East Lansing in Ingham County in 1949 and 1950 and in St. Joseph, Kalamazoo, and Missaukee Counties in 1951. Seed of Common Sudangrass was obtained from three commercial seed houses in Michigan in 1950 and from two seed houses in 1949 and 1951. To indicate different seed sources, these Common Sudangrasses are referred to in Table 1 as Common No. 1, No. 2, and No. 3.

The plots were seeded with a standard grain drill at acre rates of 30 pounds of seed and 500 pounds of 4-24-12 fertilizer per acre. Harvests were made during mid-August and October except that in 1951

ARTICLE 34-41

one harvest only was made in St. Joseph County on August 15 and in Missaukee County on October 6.

EXPERIMENTAL RESULTS

The yields of the Sudangrass varieties for the three years are given in Table 1. Over the 3-year period, Piper significantly outyielded Sweet Sudangrass in five of the six tests. The latter yielded significantly more than Piper in only one test, that in Ingham County in 1950.

TABLE 1—Yields of Sudangrass varieties in tons of 12 percent hay per acre in 1949, 1950 and 1951 in Michigan. Average of four replications.

Variety	County and year					
			1951			
	1949 Ingham	1950 Ingham	Ingham	Kalamazoo	St. Joseph	Missaukee
Piper	2.89	3.34	2.34	2.80	2.80	1.64
Sweet	2.47	3.85	1.82	2.25	2.51	1.34
Common No. 1	2.34	3.18	2.02	2.80	2.79	1.46
Common No. 2	2.23	3.04	1.98	2.57	2.62	1.52
Common No. 3	....	3.15	....	....	....	....
Tift	2.12	2.05	....	....	....	....
L.S.D. 0.05 level*	0.29	0.50	0.17	0.25	0.29	0.20

*Least significant difference between varieties.

Piper yielded more than Common Sudangrass in four of the six trials, the yield being higher in Ingham County in 1950 and significantly higher in Ingham County in 1949 and 1951 and in Missaukee County in 1951. None of the yields of Common Sudangrass was ever higher than that of Piper but one of the Common Sudangrasses yielded about the same as Piper in Kalamazoo and St. Joseph counties in 1951. Sweet yielded more than the Common Sudangrasses in only two of six tests, being higher in yield in Ingham County in 1949 and significantly higher than the Common Sudangrasses in 1950. Common Sudangrass significantly outyielded the Sweet variety in three of the four counties in 1951. There was some variation in yield among the Common Sudangrasses tested, but in no test was one significantly higher than the other.

A summary of data showing plant characteristics and responses to grazing of Sudangrass varieties in three counties in southern Michigan is presented in Table 2. Piper had the lowest amount of hydrocyanic

acid of any of the varieties tested, having only one half that of Sweet or the Common Sudangrasses. Tift was intermediate in HCN content. Although no cases of prussic acid poisoning of livestock pasturing Sudangrass have been authenticated in Michigan, other states have reported prussic acid poisoning of cattle. A Sudangrass low in HCN would be preferable to other Sudangrasses of equal yield with a higher content.

TABLE 2—Summary of plant characteristics and behavior of Sudangrass varieties for trials made in Ingham, Kalamazoo, and St. Joseph counties during the period 1949-1951. Average of four replications.

Characteristic	Variety			
	Piper	Sweet	Tift*	Common
HCN, p.p.m.†	300	630	450	590
Height, inches—Aug. 10-15	60	50	45	57
Heading date	Aug. 11	Aug. 14	Aug. 17	Aug. 7
Stem diameter	fine	medium	fine	fine
Leaf diseases‡	low	low	very low	high
Leaf fraying	low	low	low	high
Uniformity	high	medium	high	low
Grazing time, minutes§	19	35	14	13
Percent forage produced after Aug. 15	24	18	20	21

*Tested only in 1949 and 1950 in Ingham County.
†Hydrocyanic acid in parts per million of dry tillers 8 inches long. 1949 test in Ingham County.
‡*Helminthosporium turcicum* and *Colletotrichum graminicolum*.
§Minutes of grazing time spent by a dairy cow on four replicates of varieties, cafeteria style, in two periods of 3 hours each, August 14, 1949, Ingham County.

Common and Piper are somewhat taller when heading than Sweet Sudangrass and considerably taller than Tift. Common Sudangrass headed about 4 days before Piper, 7 days before Sweet, and 10 days before Tift. Sweet Sudangrass was somewhat coarser but slightly more leafy than the other varieties tested.

Tift was practically free of leaf diseases; Piper and Sweet were only slightly more susceptible. Common Sudangrass was very susceptible to leaf diseases, with a resulting excessive amount of leaf fraying and drying during the latter part of the summer. Tift, Piper and Sweet Sudangrass could be considered as having a desirable high resistance to leaf diseases.

A Guernsey cow which was allowed to graze the different varieties of Sudangrass in drill-width plots (replicated four times) showed definite preference for Sweet Sudangrass when permitted to choose

among the varieties during two grazing periods of 3 hours each. Piper was second highest in palatability followed closely by Common and Tift, which were about equal in palatability. Palatability has often been given as a reason for the selection of Sweet Sudangrass for animal grazing. However, since Sudangrass, regardless of variety, is highly palatable at nearly all stages of growth, it is believed that palatability should not be used as a criterion of using one variety in preference to another.

A high amount of recovery growth after removal of top growth in July or August is desirable to extend the season of grazing. The greatest amount of regrowth following cutting was produced by Piper followed by Common, Tift, and Sweet Sudangrass, respectively.

RECOMMENDATIONS

Based on experimental results, the following recommendations are made for those wishing to grow Sudangrass in Michigan:

1. When seed becomes available, Piper should replace other Sudangrass varieties in Michigan since it produced the greatest forage yield in most trials ranging from southern to north central Michigan. In addition to higher yields, Piper has a desirable low HCN content, a high resistance to leaf diseases, very good regrowth in late summer, and a reddish-black seed color. The distinctive reddish-black seed color would be a definite asset in maintaining the genetic purity of this variety when grown for seed. It matures relatively early, making seed production possible in southern Michigan.

2. Sweet Sudangrass cannot be generally recommended for Michigan since it has yielded less than Piper and Common Sudangrass.

3. Until sufficient seed of Piper is available for Michigan farmers, most of the state's acreage should be planted to Common Sudangrass. Sweet Sudangrass can be used in the southern two or three tiers of counties but should be planted before June 5 to permit maximum growth since it was developed for a long growing season.

CONTROLLING ALDER WITH BASAL STEM SPRAYS

By MAURICE W. DAY
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LARGE AREAS of land in the Lake States are covered with stands of alder *(Alnus incana)*. Such land usually produces very low returns, and many owners are seeking means of economically converting it to a more profitable crop. While some areas are suitable for agricultural use, drainage usually is inadequate and a forest crop is more suitable. Most alder areas are suitable for the growing of white cedar, white and black spruce, balsam fir and other valuable species.

The natural conversion of alder to a more valuable species is a slow process, and artificial methods are needed to speed up the change. The need for low-cost methods is indicated by the relatively low value of the land and by the long period of years necessary to grow a new crop of wood after conversion to a desirable species.

Previous work (2, 3) has indicated that alder, as well as several associated species, is susceptible to the newer 2,4-D and 2,4,5-T formulations now being used as silvicides. Most of the earlier work has been concerned with foliage sprays, but it is becoming increasingly apparent that basal and stump sprays will be more practicable for this species. Most alder stands are so tall that foliage spraying with ground equipment would be costly. Foliage spraying may, however, be most practicable when stands are 6 feet or less in height, or where airplane spraying is possible.

Experimental control work during the past few years has shown that a 2,4,5-T ester formulation in diesel oil is very effective as a stem spray on alder. Concentrations of 5,000 p.p.m. gave 90- to 100-percent kills in stands of alder and red maple having stems up to 3½ inches in diameter, and control was virtually 100 percent when 8,000 p.p.m. was used. When a mixture of 2,4-D and 2,4,5-T (commonly sold as "Brush-killer") was used at the same concentration, nearly as good results were obtained. On the other hand, formulations of 2,4-D alone in diesel oil

ARTICLE 34-42

did not give comparable results until the concentration had been increased to 20,000 p.p.m.

Since most brush control work for forestry purposes does not require a complete kill of the alder, the most effective and economical concentration can be determined for each job by adjusting for the peculiar needs of the project. A high degree of control will avoid the need of follow-up work later when the area has been planted.

In basal spraying, the oil solution is applied to the trunks or stems from the ground line to a height of about 2 feet in sufficient quantity to thoroughly wet the bark. The work can be done at any season of the year. Alder treated in late winter was killed as effectively as that treated in the summer. However, winter treatments are difficult when the snow is deep, and the snow cover prevents some of the lower stems from being treated.

Most basal spraying has been done with ordinary knapsack sprayers. Ordinarily, a standard coarse-spray nozzle is used. On larger operations it would be well to use nozzle equipment such as that described by Ashbaugh (1).

The need, however, has been for some method which would permit the use of power equipment. One such approach was tried out experimentally. A tract of alder was selected which was quite typical of these stands. There were 3,360 stems per acre 0.6 inch in diameter and larger. The stand was composed of 73 percent alder, with the remainder being mostly willow and small red maple. It was treated with a tractor and sprayer combination consisting of a small "crawler" tractor and a small, high pressure sprayer with 100 gallon tank mounted on rubber tires. The tractor operator also operated the spray gun and applied the solution as the tractor proceeded through the stand. This outfit was able to push its way through the stand without any difficulty and crossed and re-crossed the area until the entire area had been sprayed. In order to prevent damage to the sprayer, a protective guard for the pump and motor was installed. The tractor was also equipped with suitable guards.

This outfit sprayed one-half acre per hour, using 60 gallons of solution an acre. In this stand that amount appeared to give adequate coverage of all woody stems. From the results of this trial it would appear that, by using equipment of this type, it would be possible to treat similar stands for a total cost of about $20 an acre.

The conversion of alder lands can probably be accomplished most easily and cheaply with the aid of basal sprays, since this treatment

does not require cutting or foliage spraying. The latter is expensive when the alder is large. Treated stands can be planted to trees the spring following treatment. If the area is to be converted to agricultural use, a follow-up treatment will probably be necessary the next year, but this will not be as expensive as the initial spraying.

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SEED TREATMENT STUDIES FOR DAMPING-OFF CONTROL IN GARDEN AND CANNING BEANS[1]

REPORT OF PROGRESS

By AXEL L. ANDERSEN[2] and DONALD J. de ZEEUW[3]
DEPARTMENT OF BOTANY AND PLANT PATHOLOGY

TREATMENT of bean seed with chemicals to prevent excessive damping-off and seed decay is a protective measure used to eliminate one of the hazards in crop production. Should weather and soil conditions favor this disease complex, replanting the entire crop might be necessary. If a field so affected is not replanted, open and uneven stands result which, in turn, give an uneven harvest and a lowered return to the grower because of decreased crop yields.

Many new fungicides are offered for sale or experimental use every year. Some of these materials may be better protectants than those generally recommended at present. Cohn and deZeeuw (1) summarized the literature on bean seed treatments and agreed with previous workers that Spergon was the safest and most effective seed protectant for beans. The results from various experiment stations in the United States also have been summarized (2, 3, 4). According to McNew *et al.* (2), Spergon and Arasan were rated as the best seed protectants for beans in most of the states reporting. Cuprocide, Semesan, New Improved Ceresan, and corrosive sublimate were also mentioned as being effective. Results obtained in 1948 and summarized in the Plant Disease Reporter (3) list Phygon, Arasan and Spergon (dust or slurry) as recommended for Idaho; in Mississippi, Arasan and Spergon were the most consistent in improving emergence; and Ceresan M, 2-percent Ceresan, Semesan, and Puratized 177 were

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ARTICLE 34-43

at times beneficial. A three-state cooperative experiment rated Arasan, 5400, L-640, 854, Spergon and L-224 as equally effective, according to 1949 results (4).

The information to be presented here is the result of three years' experimentation on the improvement of stands of garden and canning beans by seed treatment. Efforts were made to determine 1) the best fungicides for use under Michigan conditions; 2) whether increased fungicidal activity resulted from the slurry method of application as compared with the dry powder; 3) toxicity, if any, of fungicides used in the dry or slurry form; and 4) whether the various varieties responded similarly to seed treatment.

MATERIALS AND METHODS

The chemicals used in these studies, their basic compositions, and the companies that manufactured and furnished the products are listed in Table 1. Seed for the 1949 experiments was furnished by the Ferry-Morse Seed Company, Detroit, Michigan, and the Associated Seed Growers, New Haven, Connecticut. All the seed for the 1950 and 1951 trials was furnished by the Ferry-Morse Seed Company.

The amount of chemical applied to the seed was either at or above the rates recommended by the manufacturer. The higher rates were generally used because of a desire to detect any possible injury which might be sustained from the application of too much material. This precaution was taken because small growers and home gardeners frequently use overdoses.

Methocel[1] and water-slurry treatments were compared with dry or dust treatments with fungicides which could be used in the various ways. The fungicides selected for these tests were generally those that had proved most effective as seed protectants in screening tests. The slurries were prepared by adding a few drops of a 7-percent Methocel solution or of water to the required amount of fungicide in the bottom of the flask. After the fungicide had been mixed to a soft paste, the beans were put in the flask and rolled around until the seed was completely covered and nearly dry. Drying was completed in the open. The dust treatments were made by placing the beans in a similar flask, a paper bag, or an envelope and pouring the powdered fungicide over the seed. Complete coverage of the seed was easily attained by shaking the seeds in the container.

[1]Trade name of Dow Chemical Company's methyl cellulose.

TABLE 1—Chemicals used in bean seed treatment studies, 1949-51

Trade or code name	Active principle	Source
Agrox	Phenyl mercury urea (6.7%)	Chipman Chemical Co.
Amine S	High Mol. Wt., tertiary amines	Alrose Chemical Co.
Arasan (Thiram)	Tetramethylthiuram disulfide (50%)	E. I. du Pont de Nemours & Co., Inc.
Arasan SF	*do* (75%)	*do*
Arquad C	Dialkyl dimethylammonium chloride	Armour and Company
Arquad 2 HT	*do*	*do*
Basic Copper Carbonate	"Fixed" or "insoluble" copper	Tennessee Corporation
Bionol A	Alkyl dimethyl benzyl ammonium chloride	General Dyestuff Corporation
Bioquin-1	Copper 8-quinolinolate	Monsanto Chemical Company
BTC	Alkyl dimethyl benzyl ammonium chloride	Onyx Oil & Chemical Co.
C & C L-224	Mercury-zinc-chromate	Carbide & Carbon Chemical Co.
C & CL-640	Copper-zinc-chromate	*do*
C & C 5400	Reaction product of dimethyldithiocarbamate and sulfur dichloride	*do*
Ceresan M	Ethyl mercury p-toluene sulfonanilide	E. I. du Pont de Nemours & Co., Inc.
Cop-O-Zink	Tribasic copper sulfate and zinc sulfate	Tennessee Corporation
Dithane D-14	Disodium ethylene bisdithiocarbamate	Rohm & Haas
Dithane Z-78	Zinc ethylene bisdithiocarbamate	*do*
Dynacide	Phenyl mercuric acetate (5%)	O. E. Link Co., Inc.
Emcol 888	Quarternary ammonium compound	The Emulsol Corporation
Octab	Octadecyl dimethyl benzyl ammonium chloride	Fairfield Laboratories
Onyxide	Octadecenyl dimethyl ammonium chloride	Onyx Oil & Chemical Co.
Orthocide 406	N-trichloromethylthio tetra hydrophthalimide	California Spray-Chem. Corp.
Panogen S	Copper 8-quinolinolate	Panogen Inc.
Panogen	Methyl mercury dicyan diamide in oil	*do*
Phygon	2, 3-dichloro-1, 4-naphthoquinone	U. S. Rubber Co.
Phygon XL	*do*	*do*
Puratized C-13-1212	Organic mercury-cadmium compound	Gallowhur Chem. Corp.
Puratized C-15-127	*do*	*do*
Quarternary 0	High mol. wt. imidazolium chloride	Alrose Chemical Company
Seedox	2,4,5-trichlorophenyl acetate (50%)	R. J. Prentiss Co.
Semesan	Hydroxymercurichlorophenol (30%)	E. I. du Pont de Nemours & Co., Inc.
Spergon(Chloranil)	Tetrachloro-p-benzoquinone (96%)	U. S. Rubber Co.
Spergon(wettable)	*do* (48%)	*do*
Tribasic Copper Sulfate	"Fixed" or "insoluble" copper	Tennessee Corporation
Vancide 51	Sodium salts of dimethyl dithiocarbamic acid and 2-mercaptobenzothiazole	R. T. Vanderbilt Co.

The treated seed was planted in randomized plots in the field at East Lansing. The experimental designs varied according to the experiment. For example, simple randomized plots were used for the screening of new compounds when one variety was used for the test. The split-plot experimental design was used, when more complex comparisons were made involving more than one variety, variations in planting date, or differences in the method of application as well as different materials. All the experiments in 1949 and 1950 were replicated four times, whereas six replications were used in the 1951 experiments.

EXPERIMENTAL RESULTS

VARIETAL RESPONSE TO DAMPING-OFF AND SEED TREATMENT

The varieties Stringless Greenpod, Topcrop, Rival, and Round Pod Kidney Wax were used in comparing the effectiveness of various seed protectants during the last three seasons. Stringless Greenpod and Topcrop showed no benefits from seed treatment, whereas Rival and Round Pod Kidney Wax stands were improved by seed treatment. The last-named variety is much more susceptible to damping-off than most others and is now used as a standard variety for comparing fungicidal efficiency of new and old compounds.

Twenty varieties were used in 1950 to determine their susceptibility to damping-off. Eleven of these varieties, namely Ranger, Dwarf Horticultural, Pencil Pod Wax, Top Notch, Black Valentine, Stringless Kidney Wax, Plentiful, Giant Stringless Green Pod, Full Measure, Rival and Tendergreen, had stand reductions of 25 percent or more. The other nine, Sure Crop Wax, Stringless Greenpod, Bountiful, U. S. No. 5 Refugee, Cherokee Wax, Contender, Florida Belle, Stringless Red Valentine and Stringless Refugee, had little stand reduction due to damping-off.

COMPARATIVE EFFECTIVENESS OF FUNGICIDES

Bioquin-1 and C & C L-640, when used as seed treatments on Stringless Greenpod in 1949, significantly reduced the stand below that of the non-treated control; but when these same materials were used on Round Pod Kidney Wax seed in 1950, Bioquin-1 did not reduce the stand below that of the non-treated control and C & C L-640 significantly improved the stand. The fungicides in the 1950 tests are compared in Table 2. In this experiment, Panogen, Phygon XL, Arasan, Ceresan M, C & C L-224, C & C L-640 and C & C 5400 seed treatments gave significant increases in stands. In 1951, 29 compounds were

compared for effectiveness on Round Pod Kidney Wax seed. The test included most of the fungicides which were effective in 1950 (Table 3). All the seed protectants used in this experiment except Amine S, which was significant only at the 5-percent statistical level, caused highly significant increases in stand. The materials are listed in order of decreasing fungicidal effectiveness. The differences between the best compound and the compound ranking 17th were not great enough to indicate statistically a significant difference at the 1-percent level.

DRY VS. SLURRY METHOD OF SEED TREATMENT

Phygon XL and Ceresan M were selected for a comparative study of the dry and slurry methods of fungicide application in the 1950 seed treatment tests. Two types of slurries were used, namely, water alone and a 7-percent Methocel solution. The results are summarized in Table 4. Again in 1951, several of the more effective fungicides

TABLE 2—Average stands of Round Pod Kidney Wax and Topcrop beans after treatment with various seed protectants, 1950

Trade or code name	Dosage (oz./100 lb. seed)	Average stand†	
		Round Pod Kidney Wax	Topcrop
		Number	Number
Panogen	3.2	118.5**	107.2
Phygon XL	4	117.8**	119.5
Arasan	2	113.0**	125.5
Ceresan M	2	104.0**	123.8
C & C L-224	2	102.5**	113.5
C & C L-640	2	95.2**	122.8
C & C 5400	2	84.5*	119.0
Dithane Z-78	2	78.5	123.0
Bioquin-1	2	76.8	121.8
Spergon	4	68.2	114.0
Panogen S	3.2	63.5	108.8
Non-treated control	...	65.0	113.8

†L. S. D. values are 16.8 at 5-percent and 22.3 at the 1-percent level; treatments significantly better than control marked with * and those highly significantly better are marked with **. Values are averages of four replicated plots with 150 seeds planted in each plot.

were compared in the dry and slurry forms on the varieties Rival and Round Pod Kidney Wax. The results are given in Table 5. An examination of the data in Tables 4 and 5 reveals that 1) the dry and slurry applications were equally effective for most compounds; 2) Ceresan M, when used in the slurry form, was highly injurious to the seed at 4 ounces (1950) but not at 2 ounces/100 pounds of seed (1951), at least for the varieties tested.

TABLE 3.—Average stands of Round Pod Kidney Wax beans after treatment with various seed protectants, 1951

Trade or code name	Physical form	Dosage (oz./100 lb. seed)	Average stand†
			Number
Semesan	powder	2.0	81.7
Orthocide 406	do	4.0	80.7
Basic Copper Carbonate	do	4.0	79.8
C & C L-640	do	4.0	79.0
C & C L-224	do	4.0	78.7
Agrox	do	2.0	75.8
Tribasic Copper Sulfate	do	4.0	75.3
Vancide 51	liquid	4.0	74.7
Cop-O-Zink	powder	4.0	74.5
Panogen	liquid	3.2	73.3
Phygon XL	powder	3.5	71.3
Arquad C	liquid	4.0	71.0
Puratized C-13-1212	powder	2.0	68.8
Quarternary 0	paste	4.0	67.8
Dithane D-14	liquid	4.0	66.6
Spergon	powder	4.0	66.5
Arasan SF	powder	3.0	65.5
Octab	do	4.0	63.8
Puratized C-15-127	do	2.0	63.7
Arasan SF	do	4.0	63.5
C & C 5400	do	4.0	63.2
Onyxide	paste	4.0	57.8
Seedox	powder	4.0	50.7
BTC	paste	4.0	50.2
Emcol 888	liquid	4.0	47.8
Arquad 2HT	paste	4.0	46.8
Bionol A	liquid	4.0	46.8
Dynacide	powder	2.0	45.3
Amine S	solid	4.0	42.7
Non-treated control	...	...	28.5

†L. S. D. values are 13.2 at 5-percent and 17.4 at 1-percent level; values are averages from six replicated plots with 120 seeds planted in each plot.

DISCUSSION

Whether seed treatment of a bean variety is necessary depends to a great extent upon the weather and soil conditions immediately after planting. Since the cost of treating seed is not very great, the practice is definitely worthwhile to all growers of garden and canning beans. In fact, many canning companies are demanding that their seed be treated before it is turned over to the growers. It was very evident from our data and observations that varieties differ in their tolerance to damping-off organisms. No doubt even the most tolerant varieties are susceptible when the conditions are favorable for the disease.

There were no significant increases in stands as a result of applying the fungicides to the seed in the slurry form as compared with the dry method of application. Nor was there any indication that a Methocel slurry was better than a water slurry in improving stands. A few advantages are gained, however, by using slurry methods. For example, many of the fungicidal dusts are extremely irritating to the respiratory system and require the use of masks by the workers. This inconvenience is largely eliminated by the slurry method of application. Furthermore, the slurry method can be used readily by both small and large growers. A small container is satisfactory for small lots of seed. For commercial lots, slurry machines are available at many local elevators.

TABLE 4—Average stands of Round Pod Kidney Wax and Topcrop beans after treatment with various seed protectants by dry and slurry methods, 1950

Trade or code name†	Form or method of application	Average stand‡	
		Round Pod Kidney Wax	Topcrop
		Number	Number
Phygon XL	Water slurry	122.8	112.8
	Methocel slurry	120.0	116.0
	Dry dust	122.5	110.2
Ceresan M	Water slurry	0.8	4.8
	Methocel slurry	27.0	1.5
	Dry dust	113.0	102.2
Control	Water slurry	57.8	105.5
	Methocel slurry	58.8	105.0
	Dry (no treatment)	53.8	108.2

†Applied at a rate of 4 oz./100 lb. of seed.
‡L. S. D. =16.4 at 5-percent level and 22.0 at the 1-percent level; 150 seeds planted in each of four replications.

Most of the fungicides were non-toxic to beans at the dosages used in the field experiments. Only Ceresan M caused significant stunting and stand reductions and only when used in the slurry form at 4 ounces/100 pounds of seed. At half the dosage, this same material appeared to cause little stunting. As a dry powder, Ceresan M was a very effective seed protectant in the field tests. The authors cannot recommend its use in the slurry form, however, because of the danger to the plants. It is quite probable that some varieties would be injured even at the 2-ounce rate with this chemical.

TABLE 5—Average stands of Round Pod Kidney Wax and Rival beans after treatment with various seed protectants by various methods, 1951

Trade or code name	Form or method of application	Dosage (oz./100 lb. seed)	Average stand†	
			Round Pod Kidney Wax‡	Rival§
			Number	Number
Spergon	Dry dust	4	87.8	82.0
	Methocel slurry	4	87.7	83.0
Arasan	Dry dust	4	87.3	81.5
Arasan SF	Methocel slurry	3	95.8	78.7
Phygon XL	Dry dust	4	90.8	77.3
	Methocel slurry	4	96.0	72.3
Ceresan M	Dry dust	2	86.5	74.8
	Methocel slurry	2	93.0	76.7
C & C L-224	Dry dust	4	91.8	84.2
Vancide 51	Liquid	4	89.2	77.2
Panogen	Liquid	3.2	70.7	73.3
Non-treated control		...	66.2	76.2

†One-hundred twenty seeds planted in each of six replications.
‡L. S. D. values are 7.1 at the 5-percent level and 9.5 at the 1-percent level.
§Differences non-significant.

RECOMMENDED SEED PROTECTANTS

Several fungicides were found to be effective seed protectants and can, in general, be recommended for use on snap or garden beans. They include Phygon XL, Arasan, and C & C L-224. Ceresan M, when limited to use as a dry powder only, was equally effective. Compound C & C L-640, Spergon, and Panogen were highly effective in one or two years.

In the 1951 tests, several other fungicides tested appeared to be as good as or better than the ones just mentioned (Table 3). Among these are Semesan, Orthocide 406, Basic Copper Carbonate, Agrox, Tribasic Copper Sulfate, Vancide 51, Cop-O-Zink, and others. All of these materials will be included in more extensive tests in 1952.

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UREA-NITROGEN APPLIED TO THE LEAVES OF CERTAIN VEGETABLE CROPS

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Nutritional sprays have been widely used for the correction of certain minor element deficiencies of some tree fruits (4). Recent results with urea (3) and magnesium sulfate on the apple (1) and phosphoric acid on some vegetables (6) have stimulated an increasing interest in the economic possibilities of foliar fertilization of crops in general (5). Comparative spray concentration tolerances and yield responses obtained from foliar application of urea-nitrogen to certain vegetable crops are herein presented.

UREA CONCENTRATION TOLERANCES

Various concentrations of urea were applied by momentarily dipping the inverted top portions of greenhouse grown seedling plants of tomato, celery, cucumber, and bean. Treatments were applied four times at weekly intervals with urea solutions varying from 0.25 to 10 percent. Dreft[1] was used at a concentration of 0.1 percent as a wetting agent in all treating solutions in these studies. The cucumber was found least tolerant and showed some leaf injury (marginal burning) with concentrations above 0.4 percent. With celery no injury resulted from concentrations as high as 1 percent. Tomatoes and beans showed intermediate concentration tolerances approximately equivalent to 0.5- to 0.7-percent solutions. However, when the above-mentioned plants were grown under field conditions and similarly treated, the concentration tolerances for urea were found to increase by approximately 50 percent with each crop.

GREENHOUSE TOMATOES

A spring crop of tomato plants of the Spartan Hybrid variety was grown in the Grand Rapids, Michigan, greenhouse forcing area, using

[1]Dreft is a sodium alkyl sulfate, marketed by Procter and Gamble.

ARTICLE 34-44

established commercial procedures. Highly productive ground beds were used, which had been treated during the previous fall, with a heavy application of alfalfa hay mulch followed by 1500 pounds per acre of an 0-20-20 fertilizer. The soil on which two of the replications (Table 1) of a randomized block design were grown was steam sterilized just prior to setting the plants whereas that for two additional replications was not. Plants were set in the ground beds March 1, at a spacing of 15 inches in the row with a distance of 3½ feet between rows. On April 25 when the plants were about 4 feet in height and the first fruit were about 2 inches in diameter, each of the four replications consisting of 10 plants each were sprayed with 0.5-percent solution of urea. Three additional sprays were applied at successive 6-day intervals. Sufficient liquid was applied in all instances to thoroughly wet the leaves.

The results in Table 1 show that four successive foliage spray applications of a 0.5-percent solution of urea during fruit development significantly increased the yield of greenhouse tomatoes. Apparently, the greatest benefits from urea sprays were derived at a moderately low level of soil nitrogen. Excessively high levels of nitrogen frequently occur in greenhouse soils following steam sterilization. A greater availability of nitrogen in the soil resulting from sterilization with steam

TABLE 1—Effect of urea sprays on the yield of greenhouse tomatoes (pounds per plant)

Treatments	Condition of Soil		Means
	Sterilized	Not Sterilized	
Control—no spray treatment	9.2	4.8	7.0
Urea spray (0.5%), four applications	9.7	6.9	8.3
Least difference necessary for significance (5%)			1.2

likely contributed to the more favorable response with urea sprays when tomato plants were grown on the non-sterilized soil. Another factor in the northern states, which may control the magnitude of response to urea sprays of greenhouse-grown tomatoes, is the carbohydrate reserve in the plant. This has been emphasized in a report of Emmert and Klinker (2), which indicates that the results obtained by

spraying urea on the foliage of spring and fall crops of greenhouse tomatoes might be decidedly different.

FIELD TOMATOES

Greenhouse-grown potted plants of the John Baer and Rutgers varieties were transplanted May 21 into a productive field of Hillsdale sandy loam soil which had previously received a broadcast application of 10 tons of manure and 1,000 pounds of 3-12-12 fertilizer per acre. The plants of the two varieties were set in a randomized block design consisting of four replications. Each treatment in each replication comprised 10 plants and utilized a 3- by 5-foot spacing. One week after field transplanting at the time of flowering the first urea spray, consisting of 0.75-percent urea, was applied. This initial application was followed by three additional successive sprays at weekly intervals. The urea foliage sprays were applied in combination with a starter solution at transplanting (Table 2). The starter formulation consisted of 6 pounds per 100 gallons of water of a 50:50 mixture of diammonium and

TABLE 2—Effect of urea sprays on early and total yield of field tomatoes (pounds per plant)

Treatments	Early Yield	Total Yield
Control—no treatment after transplanting	1.6	6.7
Starter solution at transplanting	1.8	6.7
Starter solution + four urea sprays	2.5	7.8
Least differences necessary for significance 5%	0.7	2.5

mono-potassium phosphates. Approximately one pint of the solution was used per plant. Both early (fruit harvested up to August 1) and total yields of marketable fruit were recorded.

The data as listed in Table 2 are combined for the two varieties and suggest that successive foliage applications of urea may significantly increase early yields, but that no differences were apparent for total yields. No significant varietal responses were evident.

CELERY

Plants of Cornell 19 and Utah 15 celery were started in the greenhouse and transplanted May 23 to plots located on the Michigan State College muck experimental farm near East Lansing, Michigan. Prior to transplanting the area was fertilized by a broadcast application consisting of 1500 pounds of 0-10-30, 500 pounds of sodium chloride and 50 pounds of borax per acre. A randomized block design of four replications was utilized and comprised the treatments listed in Table 3. Individual treatment plots consisted of 20 plants spaced 6 inches apart in 32 inch rows. The spray applications (Treatments B, C and E) of

TABLE 3—Effect of soil and foliage applications of nitrogen on the yield of early celery

Treatments	Yields of trimmed celery (pounds per 10-foot plot)
A—Control—no fertilizer after transplanting	32.2
B—Five foliar applications of urea (1.0%)	41.3
C—Five soil applications of urea (1.0%)	34.8
D—Soil application of ammonium nitrate—150 pounds per acre	37.7
E—Treatments "B" plus "D"	42.7
Least differences necessary for significance (5%)	3.6
(1%)	6.0

1.0-percent urea solutions were first applied May 30 and repeated on June 2, 7, 15 and July 6. In treatment C quantities of spray comparable to the foliar treatments were applied to the surface of the soil alongside the plants rather than on the leaves. The soil applications (Treatments D and E) of 150 pounds of ammonium nitrate per acre were put on as a side-dressing on June 7.

The yield data of marketable stalks in Table 3 indicate a significantly favorable response to urea foliage sprays on the yield of early celery grown on muck soil. The data further suggest that best results were obtained, (Treatment E) from nitrogen fertilization, if a combination of soil and spray treatments is utilized.

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ANNUAL ORCHARD COVER CROP TESTS IN MICHIGAN

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IN THE SELECTION of new plants for cover crop purposes, certain requirements seem obvious. These are determined by the conditions under which the plants have to grow and, also, by the purpose for which they are to serve in the orchard. In brief, the plants should meet as nearly as possible the following requirements: 1) be drouth resistant and tolerant of summer orchard temperatures, 2) germinate and become established under less favorable soil moisture conditions, 3) consistently grow and produce well, 4) be tolerant of varying degrees of soil acidity, 5) grow comparatively well on a wide range of soil types, 6) give high annual yields for abundant organic matter return to the soil, 7) have a heavy fibrous root system in addition to heavy top growth, 8) stand up well during the winter to hold drifting snow, 9) be comparatively low as to cost of seed and, 10) readily produce a good stand of plants when seed is broadcast and dragged in.

PROCEDURE

Trials to discover such plants were started at the Graham Station at Grand Rapids in 1932. Preliminary cover crop seedings were made in a 6-year-old apple orchard and a 10-year-old peach orchard. Later trial plantings were extended to newly set red tart cherry orchards, to a 14-year-old apple orchard, and a mature grape vineyard, all on the station grounds. The soil in all test blocks was a moderately fertile clay loam, varying somewhat in texture, over a clay subsoil. The cover crop plots ranged in size from 1 5 to 1 10 acre. Replicate seedings of each crop were made in the various orchard plantings.

After the ground was prepared, the seed was planted with a grain drill to eliminate uneven seed distribution and planting depth. No fertilizer was drilled in with the seed except in 1936 when 250 pounds

ARTICLE 34-45

an acre of 2-12-12 was applied with all cover crops excepting corn. Seeding dates were varied to determine the best seeding time for the cover crop plants under trial.

Before the first killing frost was expected in the fall three representative 9-square-foot samples of each cover crop were dug up with the main roots attached. These were taken at points of average plant height and stand in each plot. The soil was washed from the roots, and the samples were allowed to dry. The air-dry weights for each crop were averaged to compute acre yields.

A total of 34 different kinds of plants were tested, including legumes and non-legumes. The legumes were soybeans, cowpeas, field peas, hairy vetch, white marrow beans, pea beans, crimson clover, sesbania, and lespedeza. The non-legumes included six varieties of sorghum cane, four of millet, three of corn, four cereal grains, three root crops, rape, hemp, sunflower, and buckwheat. All of these were seeded alone, and some were seeded in combination to test their compatibility for possible use in mixed seedings. A half-and-half mixture of oats and buckwheat was used for several years as a check crop.

RESULTS

At the beginning of this study the seed was planted during the latter part of July as previously recommended. During the following 4 years the seeding dates were progressively advanced to June 6 in 1936. The comparative acre yields for the different seeding dates are shown in Tables 1 and 2. Simultaneously, different acre seeding rates were tested for the more promising cover crop plants under trial. The acre seeding rates indicated in Table 2 proved to be the most satisfactory throughout the entire test period.

The comparative acre yields shown in Table 1 are significantly in favor of the earlier seeding date. Similar increased yields in favor of the still earlier seedings were not obtained with all plants in 1936, as shown in Table 2. Soybeans and Japanese millet yielded slightly more for the July 3 seeding than for the June 6 seeding. German millet, Sudangrass, and amber sorghum yielded less for the July 3 seeding. Although the early and mid-June seedings of these tree plants produced larger acre yields, it is not believed that this increase would justify the adoption of the earlier seeding dates. Amber sorghum and Sudangrass still reached a near-mature stage and ripened some of their seeds when planted as late as early July. Allowing them more than their required growing period is not necessary, and may even prove detrimental. If

TABLE 1—Influence of different seeding dates on cover crop yields in 1933 (Air dry weights with roots attached)

Seeding dates	Buckwheat		Oats and buckwheat		German millet		Sudangrass	
	Acre yield, pounds	Percent increase	Acre yield, pounds	Percent increase	Acre yield, pounds	Percent increase	Acre yield, pounds	Percent increase
July 25.....	756	....	1,865	....	2,723	....	2,557	....
July 14.....	1,160	53.4	2,067	10.8	4,840	77.7	3,327	30.1

given the advantage of an earlier growing start, these heavy growing crops would be in a position to compete seriously with the trees for moisture during late July and early August when rainfall frequently is deficient in Michigan. Comparatively high acre yields were rather consistently obtained with seedings made in early July, as shown in Table 3. See also Figs. 1 and 2.

The data in Table 3 represent only the cover crop yields produced in a young apple orchard set in 1937, and in two young cherry orchards set in 1932 and 1935. Seedings in a 14-year-old apple orchard were discontinued after a few years' trial. Here the cover crop made a poor growth under the competitive conditions for moisture, fertility, and sunlight. As a result, this orchard was seeded to a permanent grass cover and the trees mulched.

TABLE 2—Cover crop seeding dates with respective acre yields in pounds, 1936 (Air-dry weights with roots attached)

Cover crop	Seeding date and average acre yield in pounds			Acre seeding rate
	June 6	June 20	July 3	
Oats and buckwheat (50 – 50).....	4,840	.....	.....	2 bu.
Soybeans.....	5,142	.....	5,646	2 bu.
German millet.....	6,857	6,251	6,756	12 qt.
Japanese millet.....	7,462	.....	7,865	12 qt.
Sudangrass.....	9,226	8,335	7,462	2 pk.
Amber sorghum.....	12,470	10,356	10,739	1 bu.

Straight seedings of Japanese millet were discontinued after 4 years because this crop broke down rather severely during the winter, proving less effective in holding drifting snow. Soybeans likewise were discarded after three years' trial because of light acre yield, erratic growth in the orchard, and inferior snow-holding ability and soil protection value. The oats and buckwheat mixture was inferior in all

Fig. 1. A heavy growth of Sudangrass in a young cherry orchard at the Graham Station. Although it was seeded later than recommended it does show the response this plant will make to favorable growing weather, absence of severe tree competition and a good soil. Compare this growth with that shown in Fig. 5, seeded about five weeks earlier in 1936. (Photographed just before the plants were killed by frost in late October.)

respects. Because of its acre yield, the combination mixture is indicated for general orchard cover crop use, particularly where the soil is somewhat variable in type or fertility. On such soils one or the other of the plant types in the mixture was found to predominate within certain areas of the test plots. This resulted in more uniform growth stands and higher yields. The combination mixture consisted of 1 part each of Japanese millet, German millet, Sudangrass, and 2 parts amber sorghum by volume. Seeding rate was 2½ pecks per acre. Different

Fig. 2. Amber sorghum growing in a 13-year-old apple orchard on the station grounds. It was seeded in early July with 250 pounds of 2-12-12 fertilizer per acre. The heavy growth so close to the trees was not characteristic of this or any other cover crop tested. No large tree roots extended beneath the cover crop at this particular point, and it demonstrates the kind of growth often made where competition from tree roots is not severe. However, in other parts of this and adjacent plots the cover crop growth was restricted similarly to that shown in Fig. 4, and for the same reason. Compare growth shown in Fig. 2 with that in Fig. 6, seeded about 4 weeks earlier. (Photographed in mid-October, 1936.)

proportions of seed in the mixture may be preferable for different orchards. Should one or the other of these plants grow better in any given orchard, then seedings of that particular plant probably should be made alone, or the seed of that plant should predominate in the mixture. Many other seeding combinations were tried, but with mediocre or poor results.

The significantly larger average yields produced in 1936 no doubt resulted from the 250 pounds per acre of 2-12-12 fertilizer applied with the seed. Larger acre yields probably would have resulted in the other years covered by this study had fertilizer been drilled in at seeding time. This possibility was not explored since the original purpose of this study was confined to finding plants better adapted for orchard cover crop purposes than the ones previously used. This apparent

response of the cover crop to fertilizer indicates that a possible nutrient deficiency existed in the soil of the plots, a condition which may likewise exist in the soil of other orchards.

TABLE 3—Summarized average acre yields of cover crops, 1933 to 1941 inclusive (Air dry weights with roots attached—weights given in pounds)

Year	Amber sorghum	Sudan-grass	German millet	Japanese millet	Oats and buckwheat (50 – 50)	Mixture	Soybeans
1933	9,478	3,327	4,839	.....	1,966	.....	.....
1934	9,478	5,142	5,798	.....	2,218	.....	.....
1935	9,713	5,613	3,966	2,621	1,210	.....	2,621
1936	10,739	7,462	6,756	7,865	.....	.....	5,646
1937	5,906	5,659	3,180	4,007	3,025	5,873	1,411
1938	4,789	2,924	3,075	2,268	1,815	3,831	.....
1939	8,569	5,343	6,889	.....	1,713	7,696	.....
1940	5,041	2,721	3,730	.....	.....	3,731	.....
1941	6,049	4,536	4,032	.....	.....	4,840	.....
Aver-age...	7,751	4,747	4,696	4,190	1,991	5,194	3,226

The average acre cover crop yields in the mature grape vineyard are shown in Table 4. These yields, in some instances, may vary from those produced in the young orchard plantings.

The cover crop study was extended in 1939 to a small non-bearing cherry orchard at Hart, and to a nearly mature bearing cherry orchard

TABLE 4—Average acre yields of cover crops in a mature grape vineyard, 1941 and 1942 (Air dry weights with roots attached—weights given in pounds)

Year	Amber sorghum	Sudan-grass	German millet	Japanese millet	Oats and buckwheat (50 – 50)	Mixture	Oats and field peas
1941	5,948	4,133	5,243	5,716	3,175	5,111	2,419
1942	3,730	3,003	3,497	2,721	.....	.....	.....
Aver-age...	4,839	3,568	4,370	4,218	.....	.....	.....

at Kewadin, Michigan. The soil in both orchards was a fairly fertile sandy loam. The early and late seeding dates in both orchards varied somewhat from year to year, depending upon the time the grower had available for broadcasting and dragging in the seed. Some seedings were made before fruit harvest, while others were made after harvesting was completed. For purpose of comparison, in 1941 a seeding of oats and field peas was made in the Kewadin orchard. This cover crop mixture is frequently planted in these northern cherry orchards.

Fig. 3. The effect of peat worked into the soil upon the growth of the winter wheat cover crop is very pronounced. The area on the left received no peat, the soil was hard and dry, and the growth of the cover crop was very sparse. The area on the right received one yard of peat per tree square (20 x 20) feet in the fall of 1930 and again in 1931. Here the surface soil was mellow and had a considerably higher moisture content. Rain water penetrated the soil rather freely in this area, while in the former most of it was lost through surface runoff. Both areas received identical nitrogen fertilizer applications. (Photographed June 20, 1933.)

The results obtained in the Hart orchard in 1939 and 1941 are shown in Table 5. The average acre yield of the cover crops in this young non-bearing orchard was excellent in both years, particularly when amber sorghum was grown. Heavier yields were again produced in the earlier seeded plots as was true in the Graham Station tests.

Similar results were obtained in the Kewadin orchard as shown in Table 6. The lighter cover crop yields in this orchard are due to greater competition of the larger trees and a cooler growing season. Japanese millet produced the highest yield in the later seedings indicating it is more tolerant of cool growing temperatures. German millet also was quite satisfactory in this northern orchard.

TABLE 5—Average acre yields of cover crops in a non-bearing cherry orchard at Hart, Michigan (Air-dry weight with roots attached—weights given in pounds)

Year	Seeding date	Amber sorghum	Sudan-grass	German millet	Japanese millet
1939	July 7	7,864	3,629	5,443	.....
	July 23	3,023	2,419	3,326	.....
1941	June 28	8,309	4,235	5,041	6,453
	August 5*	2,722	2,720	3,024	4,032
	August 18†	.....	.....	1,814	2,520

*Seeded just before fruit harvesting in adjacent orchards.
†Seeded immediately after harvesting was completed.

TABLE 6—Average acre yields of cover crops in a bearing cherry orchard at Kewadin, Michigan (Air-dry weights with roots attached—weights given in pounds)

Year	Seeding date	Amber sorghum	Sudan-grass	German millet	Japanese millet	Oats and field peas
1939	July 19	3,024	1,810	1,814	2,117	.....
	August 7	1,512	1,510	1,209	2,109	.....
1940	July 12	4,032	2,520	3,226	4,334	.....
	July 30*	907	806	1,411	2,721	.....
1941	July 22	904	907	957	1,058	980
	August 4	†	†	†	302	1,058
1942	July 3	2,016	1,562	2,621	2,167	.....
	July 20	1,714	1,109	1,965	1,512	.....

*Seeded the day before fruit harvesting started.
†No samples collected because of extremely poor growth of cover crop.

A rather striking difference exists in the average acre yield of the cover crops seeded between the dates of July 19 and 22 in the Kewadin orchard, for the 1939, 1941, and 1942 seasons. No definite reasons for these wide variations can be given. However, it is believed that cool temperatures during late summer and early fall were largely responsible for the light yield in 1941. The height of the August 4 seedings did not exceed 4 inches at sampling time on October 13. The soil moisture apparently was not the limiting factor in this case was indicated by the good stand of plants in the various plots. Further, the mixed seeding of oats and field peas seeded on the same date in adjacent plots, yielded an average of 1,058 pounds dry matter per acre. This yield would not have resulted if the soil had been moisture-deficient.

Fig. 4. The restricted growth of Sudangrass adjacent to a mature peach tree is characteristic of the behavior of cover crops where shading and moisture competition is severe in the orchard. A large peach root extends directly beneath the cover crop in the left foreground, and another directly in back of the tree trunk. Note the less restricted cover crop growth around the smaller cherry trees in the background. (Photographed after the first frost killed the cover crop in late October.)

DISCUSSION

After 1 to 3 years of testing most of the prospective cover crop plants were discarded as being unsuited. Poor seed germination, survival of young plants, erratic growth, or yielding capacity under competitive orchard conditions were the main reasons. At the end of the 10-year testing period only four of the original 34 plants proved worthy

Fig. 5. Sudangrass in a young cherry orchard at the Graham Station. Fertilizer was applied at seeding time at the rate of 250 pounds of 2-12-12 per acre. The young trees have not as yet restricted the growth of the adjacent cover crop, but this will become evident as the trees grow larger. Compare the growth above with that shown in Fig. 1 which was seeded about 5 weeks later during the 1933 season. (Photographed mid-October, 1936.)

of recommendation as annual cover crops in orchards, either when seeded alone or in combination mixtures. These were amber sorghum, Sudangrass, German millet, and Japanese millet, listed in the order of heaviest acre yield produced. Two other strains of sorghum cane, Sweet Amber and Waconia, were about equal to amber sorghum in yield during a 2-year test period, but no better.

The ability of a cover crop plant to produce consistently heavier

Fig. 6. Amber sorghum in a young cherry orchard at the Graham Station. The cover crop was seeded in early June with a fertilizer application of 250 pounds of 2-12-12 per acre. The young cherry trees are hidden from view by the tall-growing sorghum. When growing close to young trees such tall growth may lodge against them and cause limb breakage when followed by a heavy snowfall. Compare above growth with that in Fig. 2, seeded about 4 weeks later. (Photographed mid-October in 1936.)

acre yields of returnable organic matter was of primary consideration in this study. The importance of organic matter in the soil, before and after it is converted into humus, cannot be overemphasized. It loosens the heavier soils and binds together the lighter ones and reduces water erosion by increasing the water absorption and retention capacity of the soil. Likewise, it increases the activity of beneficial soil bacteria, with subsequent increased liberation of plant nutrients. Further, organic matter provides better soil aeration, thereby encouraging wider penetration and distribution of tree roots.

In addition to supplying a maximum of returnable organic matter, the stiff-stemmed types of cover crop plants were not completely flattened to the soil by wind and wet snow during the winter months. Thus, they effectively held drifting snow. A good blanket of snow insulates the soil against deep freezing, reducing to a minimum the danger of possible injury to the tree roots during periods of low temperatures. Also, such unfrozen soil permits water to penetrate more freely during the winter. Furthermore, a cover crop that effectively holds snow will likewise hold the leaves shed by the trees. In the case of a mature grape vineyard the air dry weight of the leaves amounted to 1,316 pounds per acre. For 16-year-old Bartlett pear trees the total was 1,242 pounds per acre, and 2,106 pounds per acre for 9-year-old Montmorency trees, based on the weight of foliage picked from representative plants.

The growth volume produced and the ground area that the cover crops occupied in orchards of different tree ages and sizes, varied considerably. In newly set or young orchards the cover crop showed little or no restriction in growth adjacent to or near such young trees. However, as the trees became older and occupied more area below and above ground, the cover crop growth area was progressively reduced due to competition. In the older apple orchard, where the tree roots more fully occupied the whole surface soil area, the cover crop grew very poorly. The factors of shading, competition for nutrients and moisture, along with possible toxic spray residues in the soil, restricted the establishment and growth of the plants to the area beyond the drip of the branches. This emphasizes the importance of growing the greatest possible volume of organic matter in the clean cultivated orchard during the time that the trees are young. In well grown peach orchards where the trees are more closely spaced, this period of reduced cover crop growth is reached at an earlier time than in a wider spaced apple orchard.

SUMMARY

Of the various plants tested, amber sorghum, sudangrass, German and Japanese millets, in the order named, were best adapted for annual cover crop purposes in the younger Michigan orchards. Seeding mixtures of these four plants produced acre yields next to amber sorghum in volume.

The best seeding period for these plants is July 1-10 in the Grand Rapids and eastern Michigan fruit-growing areas, a week later in southwestern Michigan, and 10 days to 2 weeks earlier in young orchards located in the northern sections of lower Michigan.

After-harvest seedings of cover crops are preferable for bearing cherry orchards in the northern areas. Seeding mixtures of oats and field peas, or winter grains are most satisfactory considering the short growing season remaining.

In bearing peach and plum orchards early July seedings of amber sorghum, Sudangrass, and the millets frequently reduced fruit size because of competition for soil moisture. Winter rye seeded during the latter half of August was less competitive and more desirable in these orchards.

In mature apple and pear orchards kept under clean culture, mid-August or later seedings of winter wheat or rye gave a more uniform and complete ground cover on the heavily shaded orchard floor than any of the plants tested.

Complete fertilizer applied at the time of seeding greatly increased the volume of cover crops produced per acre in 1936, indicating the advisability of this practice in Michigan orchards.

PROGRESS REPORT ON THE WOODED WATERSHED OF THE MICHIGAN HYDROLOGIC RESEARCH STATION

By JAMES L. SMITH[1] and GEORGE A. CRABB, JR.[2]
DEPARTMENT OF FORESTRY AND MICHIGAN HYDROLOGIC RESEARCH STATION

THE Michigan Hydrologic Research Project was established at East Lansing in 1940, as a cooperative study between the Soil Conservation Service of the U. S. Department of Agriculture and the Michigan Agricultural Experiment Station. It was desired to determine the effect of various types of land use on the hydrology of soils under northern conditions. The objectives of this study are twofold:

1) To determine the manner in which freezing and thawing of soils on watersheds with varying types of land use contribute to runoff, erosion and flood flow under northern conditions, and

2) To determine the fundamental hydrologic relationships of typical Michigan soils under varying types of land use, with special emphasis upon the movement of water through the soil profile during the fall and winter months.

Three watersheds, as nearly alike in every respect as was possible (with the exception of cover) were selected for the study. Two were to be handled under approved, prevailing current farming practices. These lie side by side on farm lands belonging to Michigan State College about 2 miles from East Lansing. The other watershed is located on lands of the Rose Lake Wildlife Experiment Station of the Michigan State Department of Conservation, approximately 10 miles from East Lansing. This watershed was considered typical of a good, well-stocked oak-hickory farm woodlot.

It is with the wooded watershed that this paper is most concerned. However, if the hydrology of this watershed is to be properly evaluated, it must be compared with the cultivated watersheds.

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ARTICLE 34-46

Soils of the two cultivated watersheds are of the Hillsdale, Miami and Metea series, while those at the wooded watershed are Hillsdale and Miami. These soils are all similar.

The three watersheds are quite similar as to size, cultivated watershed "A" having an area of 1.981 acres, cultivated watershed "B" 1.349 acres, and the wooded watershed 1.650 acres.

A careful comparison of the slope-class distribution of the watersheds in question was made. It was found that the weighted average slopes were 6.0 percent for cultivated watershed "A", 6.5 percent for cultivated watershed "B", and 6.1 percent for the wooded watershed.

It can thus be seen that, in every instance—soils, size, slope, etc., these three watersheds are as similar as it is probable to find in nature. The basic difference between the watersheds is, of course, that two are under cultivation while the other is under forest cover. The cultivated watersheds have been handled under rotations of corn, oats, and a mixture of brome grass and alfalfa.

Fig. 1. View of runoff and erosion measuring installations on the wooded watershed, Michigan Hydrologic Research Station. Note Ramser Divisor Tank at left, wier plate in center, and type 3-H metal flume in center behind foot bridge. Stage recorder is mounted in instrument house.

Instrumentation for the three watersheds is essentially the same, with one exception: at the time the project was initiated, material restrictions prohibited the laying of electric lines to the wooded watershed. Therefore, the instruments at this watershed are not electrically operated. However, the data gathered by the instruments at the three watersheds are essentially the same.

The rain gages used in this study are U. S. Weather Bureau Standard type, 8-inch, non-recording rain-and-snow gages; similar non-recording rain-and-snow gages equipped with Nipher shields, and Fergusson recording rain-and-snow gages, operated with a chart-holding clock which makes one revolution each 12 hours.

The hygrothermographs have hair-actuated humidity-recording bimetallic elements. These are operated with clocks making weekly revolutions.

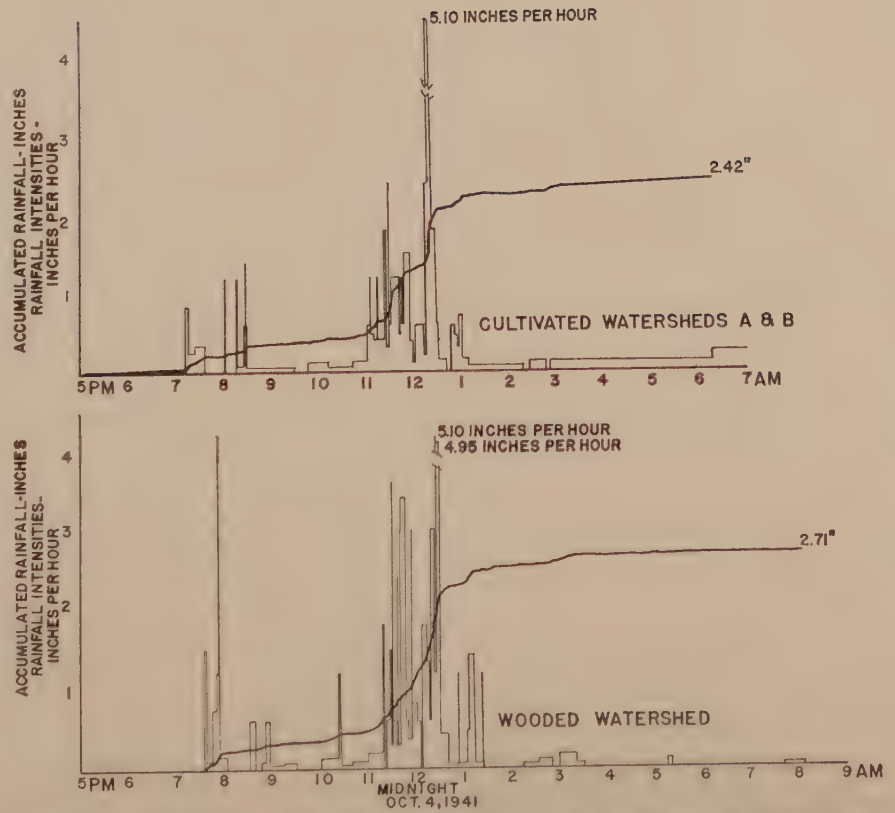
The runoff-measuring installations at each watershed consist of concrete approach sections leading to a type 3-H sheet metal flume. The runoff-recorder is of reversing-pen design. The recorder clock operates at the rate of one revolution each 12 hours.

The erosion-measuring installations consist of silt-boxes with a storage capacity of 320 cubic feet for the cultivated watersheds and 200 cubic feet for the wooded watershed. These boxes are equipped with 8-foot weir-plates, Ramser divisors, and overflow catchment tanks.

The wind direction and velocity installations consist of towers with three cup anemometers (1/60 mile contact) and vanes. The recorders register velocity and direction in octants for one minute out of each quarter hour on weekly charts. These operate with totalizers which count every sixtieth mile of wind movement.

Further instrumentation consists of a pyrheliometric installation to record the receipt of radiant solar energy at the cultivated watersheds. This comprises an Eppley, 10-junction pyrheliometer the output of which is recorded by a Leeds & Northrup recording potentiometer. Soil moisture is determined at the cultivated watersheds by means of Bouyoucos electrical resistance blocks and a Bouyoucos variation of the Wheatstone bridge. Soil moisture at the wooded watersheds is determined gravimetrically. Soil temperatures are recorded manually and automatically at the cultivated watersheds, and by means of a clock-driven thermograph at the wooded watershed. Evaporation losses are recorded by a black-pan evaporimeter, with a weekly chart.

It will be noted that the instrumentation on the three watersheds is such that a rather complete picture of the hydrology, and nearly all



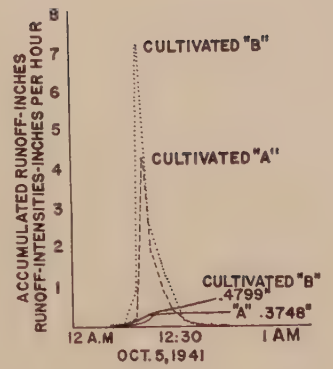


Fig. 2. Comparative hydrographs for the storm of October 4, 1941, for cultivated watersheds "A" and "B", and the wooded watershed.

the factors affecting the hydrology of areas under different types of cover, is easily obtained.

Figure 2, showing comparative hydrographs for the storm of October 4, 1941, demonstrates the effectiveness of forested cover in increasing infiltration.

Fig. 3. View of the wooded watershed, showing typical hardwood cover, and litter on the surface.

This was a major storm with high precipitation intensities and conditions favorable to producing runoff. The cultivated and wooded watersheds were subjected to peak precipitation intensities of 5.1 inches an hour. The cultivated watersheds were subjected to this intensity for a period of 2 minutes. This was the only peak intensity for the cultivated watersheds that exceeded 3 inches an hour. These watersheds were subjected to an intensity of over 2 inches an hour on only one other occasion. The wooded watershed was subjected to the 5.10 intensity for 1 minute and to intensities of over 3 inches an hour on five separate occasions during the storm. Two of these were in excess of 4 inches an hour for a total of 3 minutes, while two others were in excess of 2 inches per hour for a total of 2 minutes. The wooded

watershed had a mass total precipitation of 2.71 inches—the cultivated watersheds each had a mass total precipitation of 2.42 inches an hour.

With higher precipitation intensities and higher mass precipitation, the wooded watershed showed no runoff. The cultivated watersheds, under small grain cover, showed runoff intensities of from 4.2 to 7.1 inches an hour, and the loss of total precipitation to runoff varied from 0.37 inch for watershed "A" to 0.48 inch for watershed "B"—a loss of 16 percent for watershed "B" and 20 percent for watershed "A".

An examination of these data shows a much higher absorption of precipitation by forested than non-forested soils, and thus yields of less water as overland flow than the cultivated area. The reasons for this are manyfold.

Overland flow (surface runoff) occurs after the infiltration capacity is exceeded by the rate of precipitation for a time sufficient to fill depressions. After depressions have been filled, a sufficient depth of water must be built up on the surface of the ground to overcome the resistance of twigs and leaves on the ground to the flow of water. After this resistance has been overcome, and only then, can the water form ephemeral channels and flow off. While the water is being slowed in this manner, it has still further opportunity to infiltrate the soil.

The ability of a soil to absorb water is governed by several factors: among the more important are litter and debris on the ground; porosity, texture and structure of the soil; cavities left by dead vegetal roots; animal borings, and the amount of humus in the soil. A forest cover offers one of the best known methods for building a soil with the foregoing characteristics. Such a soil acts as a sponge in absorbing water, and more water at a greater rate of precipitation is required to saturate it than would be required for a soil under cultivation, regardless of whether it is barren or covered.

Reference to the 11-year hydrologic summaries (Figs. 4, 5, and 6) shows the soil loss for cultivated watershed "A" to be 31.938 pounds an acre and that of cultivated watershed "B" to be 56.235 pounds an acre. The greater portion of this loss occurred while the watersheds were planted to row crops. The soil loss for the wooded watershed over the same period has amounted to only 62 pounds an acre. The same charts reveal that watershed "A" yielded 50 inches of runoff, watershed "B", 44.48 inches of runoff, while the wooded watershed lost only 5.96 inches as runoff. This water loss, amounting to 14.5 percent for cultivated watershed "A", 13.4 percent for cultivated watershed "B", and 1.7 percent for the wooded watershed, is a serious matter

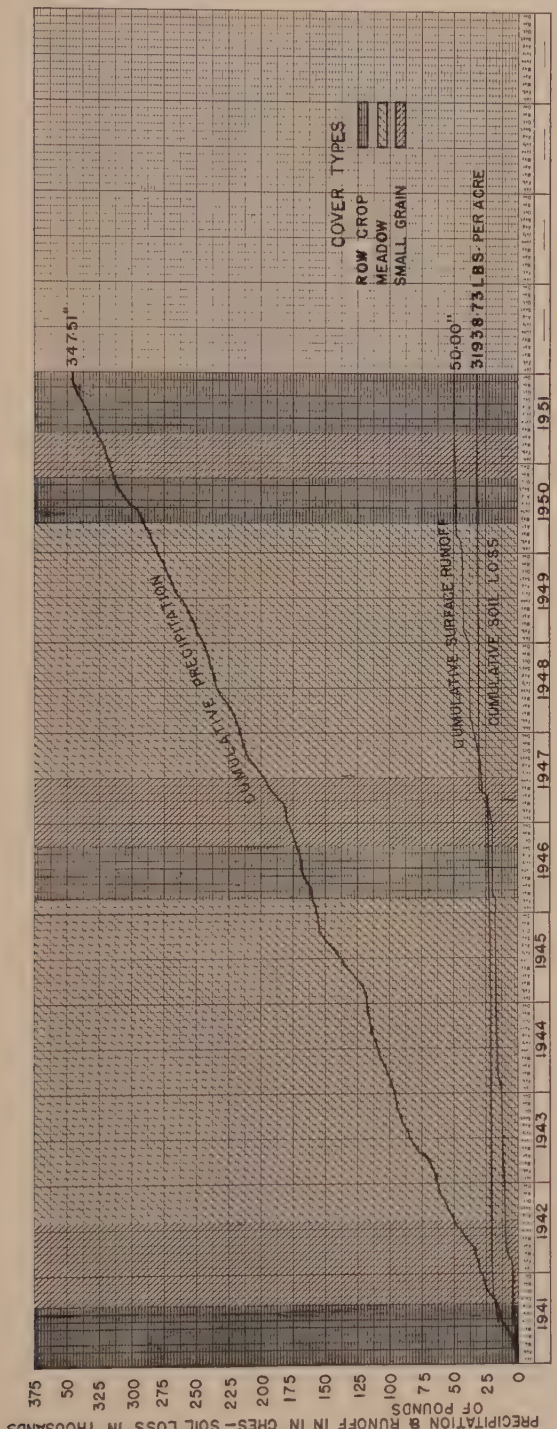


Fig. 4. Eleven-year hydrologic summary, cultivated watershed "A", Michigan Hydrologic Research Station.

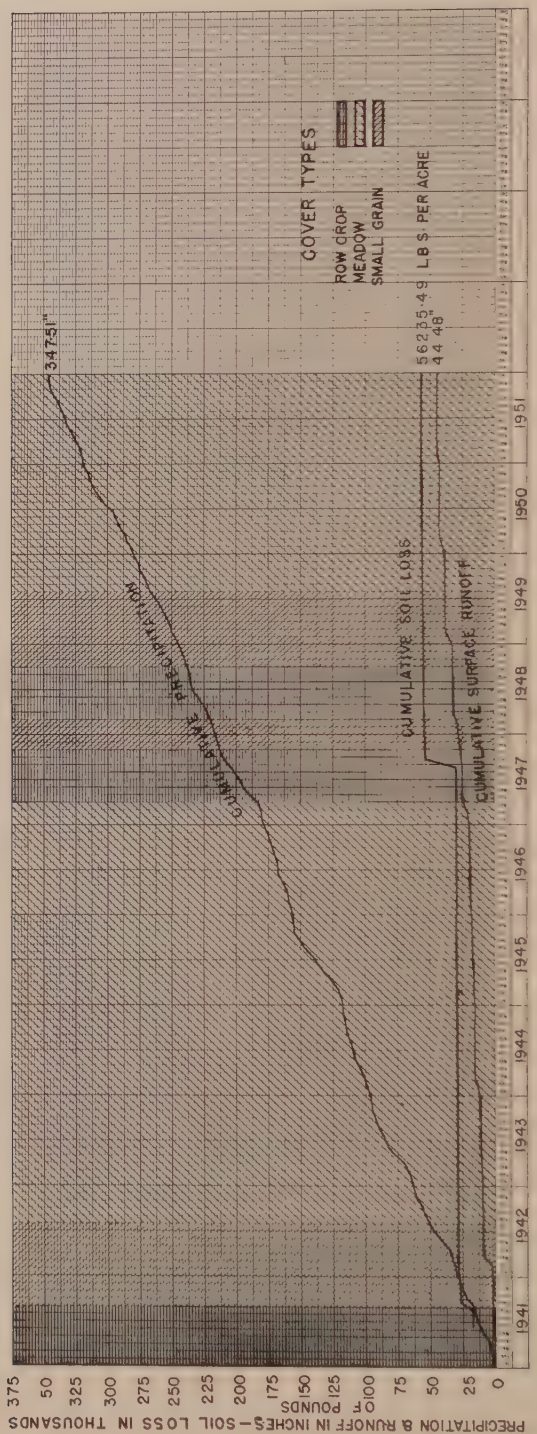


Fig. 5. Eleven-year hydrologic summary, cultivated watershed "B", Michigan Hydrologic Research Station.

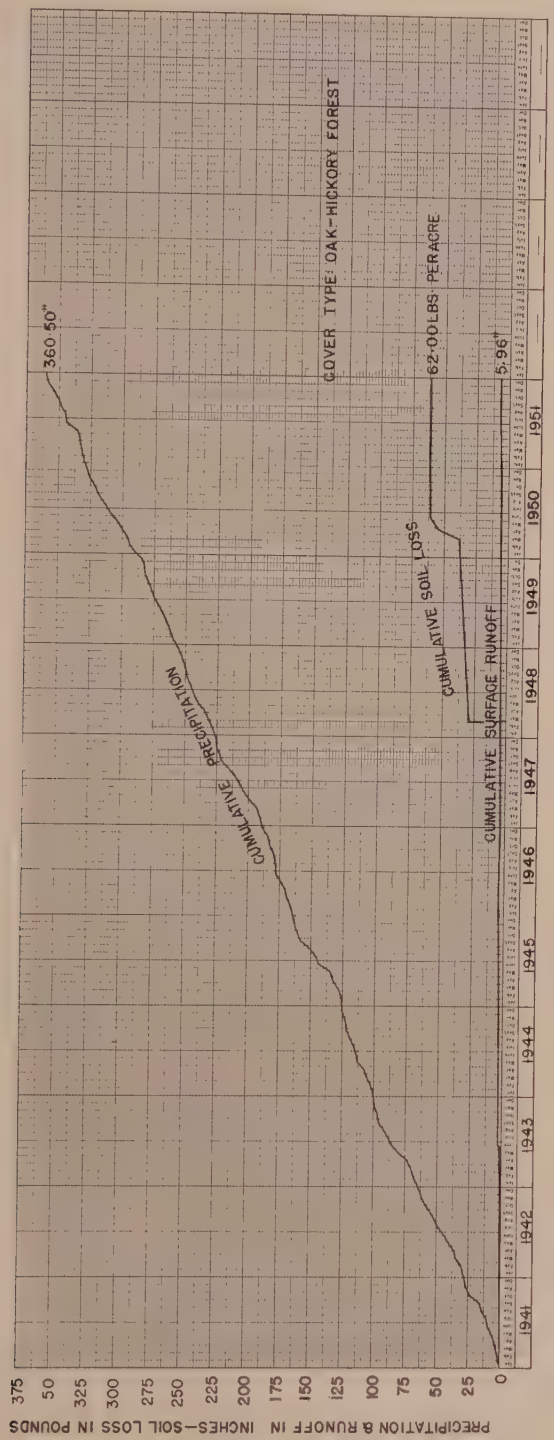


Fig. 6. Eleven-year hydrologic summary, wooded watershed, Michigan Hydrologic Research Station.

in an area with an average annual rainfall of 31.43 inches, and clearly demonstrates the valuable part timberlands play in recharging the ground-water supply, which other studies indicate is rapidly dwindling. This set of figures also explains, in part, the reason for the difference in erosion losses on the watersheds. Runoff is needed in order to produce water erosion. The faster the water flows, and the fewer impediments that slow its flow, the more soil and the larger the soil particles the water will carry off.

If the soil is not protected by some vegetal cover, rain beating down tends to compact it and reduce its permeability. Fine particles are splashed down into the soil pores and result in further sealing. If soil is thus sealed, its infiltration rate is reduced and more of the precipitation is lost as runoff than would normally be the case. A heavy mulch of leaves and straw will protect the soil surface and prevent sealing. Also effective is a forest cover. Under this type of cover, the raindrops are slowed in their fall by striking leaves of the vegetation while falling, and by falling on the heavy mulch of leaves and twigs on the forest floor.

A comparison of the cultivated and wooded watersheds reveals that the two types of cover had considerable effect on the soil temperature. Soil temperatures were generally more stable in the wooded watershed—lower in summer and higher in winter—than those at similar depths in the cultivated watersheds. Under wooded cover at 1 inch depth, temperature lagged from 2 to 30 days behind those of the crop cover in reaching the freezing point. Also, the wooded watershed tended to thaw earlier in the spring, and temperatures rose above the thawing point from 9 to 17 days sooner than at a similar depth in the cultivated watersheds. In the woods, soil temperatures seldom fell below freezing at a 6-inch depth, whereas under cultivation the soil at the same depth was seldom warmer than this temperature during January, February, and March.

Several important factors affect runoff, including total amount and maximum intensity of the rainfall, and infiltration capacity of the soil. At East Lansing a maximum intensity of 2 inches an hour or more, combined with a rainfall of 0.8 inch or more, has been found to produce runoff on the cultivated watersheds, regardless of the vegetal cover, unless the soil had a very high infiltration capacity at the beginning of the storm. In contrast, the wooded watershed has demonstrated its ability to absorb storms of over 2 inches total rainfall and over 5 inches an hour intensity without producing runoff. So long as the infiltration

capacity is high, the wooded watershed can absorb large mass rainfalls and heavy intensities. Under winter conditions, however, if the soil is frozen the infiltration capacity drops to virtually zero. Precipitation falling on such a surface has no recourse except to appear as runoff. In the early spring, the melting of accumulated snows may also saturate the soil under wooded cover, and some small amount of the added precipitation may also appear as runoff.

In October 1951, officials of the Soil Conservation Service; Department of Forestry, Michigan State College; Michigan Agricultural Experiment Station, and the Rose Lake Wildlife Experiment Station of the Michigan State Department of Conservation, agreed that, with 11 years data now accumulated from the wooded watershed, it would be advisable to alter the cover conditions in order to determine the effect of heavy cutting upon forested watersheds.

Fig. 7. View of wooded watershed following completion of commercial clear-cut operations. All timber greater than 5.45 inches in diameter was cut to give comparative hydrologic data under altered cover conditions.

During the winter of 1951-52, all timber on the watershed from 5.45 inches up was removed from the watershed and surrounding

fringe area in a commercial clear-cut operation for saw logs and cord wood. A young growth of oak, hickory, and cherry was left on the area, and it is anticipated that natural reforestation will occur.

Data for the next 10 years from this area should provide concrete figures upon the effect of this type of cutting on runoff, erosion, possible removal of some of the litter cover on the forest floor and a probable shallowing of the humus layer of the soil with its attendant effect upon such matters as soil temperatures and infiltration.

A STANDARIZED PRESSURE TEST FOR MOISTURE IN GRASS-SILAGE MAKING

By S. T. DEXTER
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SUCCESS OR FAILURE in making hay-crop silage is largely dependent on ensiling forage of the proper moisture content. In this article, a simple test for determining the proper moisture content is described.

Experience has shown that silage must be wet enough to pack well in order to press out and keep out excess air. If there is excess air, moldy silage is produced or undue heating occurs in the body of the silage. Experience has also shown that it is not desirable to have the packing proceed to such a degree that considerable juice is expressed from the chopped forage. Excess juice results in seepage and loss of nutrients, and leads to poor fermentation and silage having an offensive odor.

In general, then, the silage at any point in any silo should be wet enough to pack well and prevent excessive heating but not so wet that the pressure exerted upon it by excess packing or depth of silage, will squeeze out juice. So long as the silage is between these extremes, the exact percentage of moisture is of little consequence.

EFFECT OF PRESSURE IN SQUEEZING OUT JUICE

The proper moisture content for grass silage depends upon the pressure to which it will be subjected. Thus, to avoid expressing juice, the silage at the bottom of a silo where pressures are great must be drier than what would be necessary at the top, where pressures are much less.

So far as pressure is concerned, silage 7 feet deep in a trench or stack corresponds roughly to the silage in the *top* 7 feet in an upright silo. Therefore, such silage may properly be wetter than that at the bottom of an upright silo. Wilting that is necessary before storage in deep layers in an upright silo may be unnecessary or even harmful when a trench is used.

ARTICLE 34-47

DOWNWARD PRESSURE PER SQUARE INCH IN A SILO

Based on the weight of silage, a depth of about 3 feet of silage is required to produce one pound of pressure per square inch. Table 1 shows the approximate pressures at various depths of silage.

TABLE 1—Approximate pressure in pounds per square inch on silage at the bottom of the following depths of silage

Depth	Pounds per square inch
10	3
15	5
30	10
45	15

METHOD OF MAKING THE TEST

Before putting the chopped forage in the silo, it can be tested as to moisture content by applying the appropriate pressure and observing if juice is squeezed out.

How to obtain 5, 10 or 15 pounds pressure per square inch:

Various pressures per square inch can be obtained by applying one's own weight on small wooden blocks of various sizes. Thus, 200 pounds resting on 20 square inches would give a pressure of 10 pounds per square inch. Table 2 gives suggested dimensions of pressure blocks for persons of various weights.

TABLE 2—Suggested dimensions of blocks, cut from one-inch boards, to give about 5, 10, or 15 pounds per square inch, when supporting persons of various weights

A person's weight, pounds	Dimensions in inches of wooden block to give pressure					
	5 pounds		10 pounds		15 pounds	
	Area, Sq. In.	Dimensions	Area, Sq. In.	Dimensions	Area, Sq. In.	Dimensions
140	28	6 x 4 ¾	14	4 x 3 ½	9.3	3 x 3
160	32	6 x 5 ¼	16	4 x 4	10.7	3 x 3 ½
180	36	6 x 6	18	4 x 4 ½	12	3 x 4
200	40	6 x 6 ¾	20	4 x 5	13.3	3 x 4 ½
220	44	6 x 7 ¼	22	4 x 5 ½	14.7	3 x 5

For example, if the silage is to be about 30 feet deep, one will note from Table 1 that the pressure will be about 10 pounds per square

inch at the bottom. If one weighs about 180 pounds, a block 4 x 4½ inches is suitable for use in testing, as shown in Table 2.

How to obtain a sample:

Run some of the forage to be tested through the chopper and take a sample of about half a bushel. If a sample is being prepared without ordinary machine chopping (as with shears or a knife) it is necessary to rub the sample roughly in the hands to bruise it about as much as the machine would, since, the more a sample is bruised, the easier juice can be squeezed from it.

How to determine if juice is being pressed out:

First, a pile of the chopped forage is spread out on the floor, to give a smooth firm layer 2 or 3 inches thick. On this is spread a sheet of absorbent tissue paper, such as facial tissue. Another layer of chopped forage is placed on top of the tissue paper. On top of this, a suitable pressure block is placed. By standing on one foot on this block for one minute, one can determine how readily juice is pressed out, by observing the wet spots that are formed by the juice on the paper. It is evident that the paper will stay completely dry if no juice is pressed out, and that the paper will become soaking wet if juice is pressed out to any great degree.

If, after 60 seconds of squeezing, much more than 25 percent of the area of the paper is wet with juice spots, the forage is too wet; to the contrary, a few wet spots should be found, perhaps 10 percent of the area of the paper, or the sample must be judged too dry.

An example of tests on samples wilted to various degrees:

Samples of green forage were tested after being wilted to various degrees. The percentage of moisture was determined chemically, to show how a drier sample gives fewer wet spots. Pressures of both 10 and 15 pounds pressure per square inch were used, to show that a higher pressure gives more wetted area. The actual figures are given in Table 3.

It is suggested that blocks to give 5, 10 and 15 pounds pressure per square inch at the tester's weight should be prepared and kept readily available. A double test, for example at both 10 and 15 pounds pressure per square inch, helps in gaining experience with this method, takes only an additional minute, and is therefore recommended.

TABLE 3—Estimated percentage of area of facial tissue wetted in one minute by juice squeezed by 10 or 15 pounds pressure per square inch from chopped forages wilted to different moisture contents

Hay crop	Percent moisture	Percent of area of paper wetted	
		10 Lb. pressure	15 Lb. pressure
Alfalfa, early bloom	72.5	20	50
	66.3	5	30
	58.3	0	0
Alfalfa, bud stage	73.8	75	75
	70.0	10	20
	63.5	1	10
Timothy	67.2	5	20
	56.3	0	0
Red clover, early bloom	76.6	40	60
	72.3	10	30
	67.6	5	5

IMPROVEMENT OF POTATO CHIP COLOR BY HOT WATER TREATMENT OF SLICES

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DEPARTMENT OF FARM CROPS

IT IS COMMON knowledge in the potato chip industry that various lots of potatoes differ greatly in the color of chips produced. In general, light-colored chips are preferred because of their better flavor and "eye-appeal". Dark color in potato chips is at least partly due to excessive content of reducing sugars in the slices.[1] Partial removal or avoidance of these sugars by storing the tubers at temperatures of 50-60° F. is more or less standard practice. For potatoes previously stored at temperatures below 45 F., a storage period of several months at temperatures gradually increasing to 70° F. may be required before the potatoes reach chipping condition. Obviously, such a practice introduces major problems as to sprouting, rotting, and special storage structures. Details need not be discussed here.

It is by no means an uncommon practice to attempt to improve the color by various other treatments of the slices. This article describes attempts to improve color by diffusion of the sugars from the slices following treatment by immersion in water at various temperatures. Such treatment, it was anticipated, would cause various degrees of injury to the membrane system of the tuber, and would permit differential diffusion of cell contents. Thus, it might be conjectured that slight injury to the cell membranes might permit diffusion of small, readily diffusible molecules, such as sugar and minerals, while more severe treatment might cause injuries that would permit extensive diffusion of larger molecules, such as protein or soluble starch.[2]

EXPERIMENTAL PROCEDURE

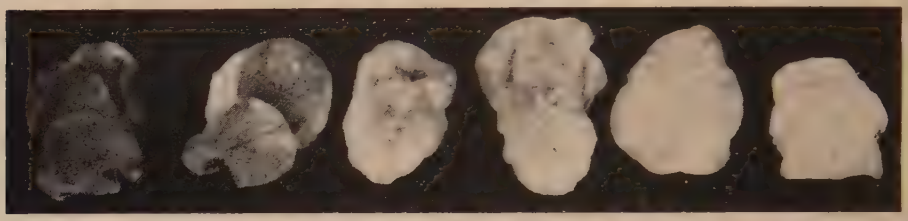
In order to produce chips uniformly dark in color, the Pontiac variety was generally used. A standard method of frying the slices

[1]Denny, F. E. and N. C. Thornton. Factors for color in the production of potato chips. C.B.T.I. 11(4):291-303. 1940.

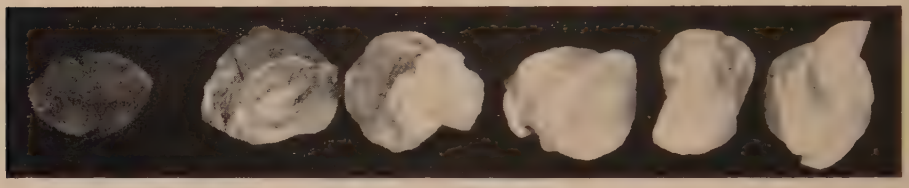
[2]Dexter, S. T. Studies of the hardiness of plants: A modification of the Newton pressure method for small samples. Plant Physiology 4: 721-726. 1932.

ARTICLE 34-48

was used throughout; the initial temperature of fat was 385° F., and the final temperature, 355° F. Preliminary trials showed that great improvement in color resulted from short exposure of slices to hot water at temperatures from 55° to 100° C. when followed by soaking in cool tap water.



Immersed for ½ minute.



Immersed for 1 minute.

Control: Cold water only ½ hour | 40°C. | 60°C. | 70°C. | 80°C. | Boiling

Fig. 1. Slices of Pontiac potatoes were immersed in water at the temperatures shown for ½ minute (upper row) and for 1 minute (lower row). Extraction in tap water for ½ hour followed, and then the slices were cooked. Note the change in color.

From Fig. 1, it can be seen that soaking slices in tap water at 10° C. (50° F.) did not improve color appreciably. A warm water treatment for 30 seconds at 40° C. gave some improvement in color, but not until the temperature was raised to 60° C. (140° F.) was the color markedly reduced. It may be noted that at the two highest temperatures, the chips curled considerably and appeared greasy in texture. Such over-treated chips are very brittle, seem thinner than what they really are, and lack flavor.

In order to establish what losses might have occurred from the potato slices in the course of a short immersion in warm water, and subsequent extraction, a more detailed experiment was set up. This included chemical analyses of the slices and the extract after various periods of soaking. Thirty-gram samples of slices were immersed for 1½ minutes in water at 70° C. (158° F.). This treatment appeared to be as drastic as would ever be required.

This was followed by extraction periods of various lengths in 150 cc. of water at room temperature. The progress of extraction was followed not only by the analyses of the slices and the extract, but by the color of the cooked slices. Analyses were made for reducing sugars, total sugars, proteins, and total solids, under the direction of Dr. E. J. Benne, Department of Agricultural Chemistry. In this way, it was possible to determine how rapidly extraction took place, what constituents were extracted, and to what degree.

The data in Table 1 show clearly that the soluble sugars decreased rapidly when the potato slices were soaked in distilled water following the hot water treatment, but that they decreased negligibly in the slices soaked without such hot water treatment. The water in which the heated slices were soaked soon became quite cloudy. The analyses showed a considerable removal of proteins, as well as sugars. The total solids extracted by soaking for 15 minutes constituted 1.21 percent of the fresh weight of the tubers. Since the total solids were only 18.5 percent, this is a loss of about 6.6 percent of the tuber substance. The amount of the protein lost in 15 minutes was about 27 percent, whereas

TABLE 1—Analyses of extracts and tuber slices after immersion in hot water and soaking in cold water

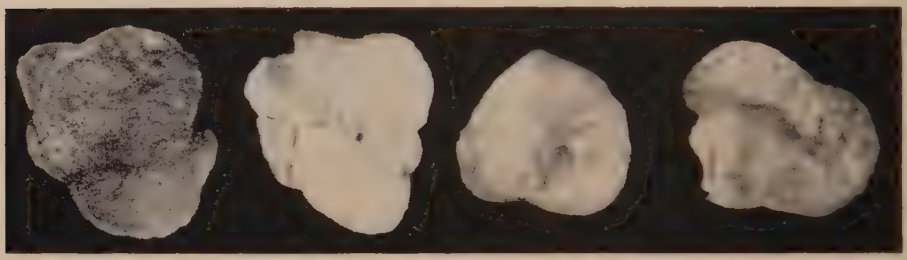
After being immersed in water at 70°C. (158°F.) for 1½ minutes, the potato slices were soaked for varying periods of time in cold water. The analyses of the slices and of the extract after these periods of extraction are shown in the table, and show the progress of extraction of sugars and other substances from the tubers.

Period of extraction in cold water, minutes	Total solids, percent*	Protein, percent*	Total sugar, percent*	Reducing sugar, percent*	Non-reducing sugar, percent*
	ANALYSES OF THE EXTRACTS				
0–15 (following hot treatment)	1.21	0.49	0.21	0.12	0.09
15–30	0.72	0.27	0.12	0.10	0.02
30–60	0.54	0.19	0.08	0.04	0.04
Total (sum of above) 0–60	2.47	0.95	0.41	0.26	0.15
Cold (0–60 no hot treatment)	0.40	0.06	0.02	0.02	0.00
	ANALYSES OF TUBER SLICES				
0 (direct from potato)	18.5	1.77	0.56	0.41	0.15
0–15 (following hot treatment)	....	....	0.11	0.00	0.11
15–30 (following hot treatment)	....	....	0.00	0.00	0.00
30–60 (following hot treatment)	....	....	0.01	0.00	0.01
Cold 0–60 (no hot treatment)	....	....	0.53	0.38	0.15

*Percent expressed on the fresh weight of tuber slices.

practically all of the sugars were extracted. When the slices were soaked in cold water, without hot water treatment, the total solids lost were about one-third as much as in 15 minutes soaking after a hot treatment was given, while sugar and protein loss was reduced to about one-tenth. By simple soaking in cold water for 1 hour, about 1/30 of the sugars, 1/30 of the protein and 1/45 of the solids were left in the wash water. The size of potato cells and the thickness of the slices suggest that this loss was largely due to the contents of the cut cells on the face of each slice.

When the potato slices were fried, following extraction, color was excellent in all cases, but when extraction was continued longer than 15 minutes, the chips appeared somewhat greasy (Fig. 2). From the results of this and other experiments, it appears that the soaking period after the hot treatment can be reduced to less than 15 minutes.



Control: Soaked in cold water only for 1 hour **15 minutes** **30 minutes** **60 minutes**

Fig. 2. Following treatment in water at 70° C. for 1½ minutes, 15 minutes of soaking in cold water gave chips of excellent color. With longer extraction times, the chips appeared greasy.

In most of these experiments, the Pontiac potato was used, since it can be depended upon to give uniformly dark colored chips. When slices of more desirable varieties were used, and such drastic improvement was not required, lower temperatures, shorter durations of hot water treatment, and shorter periods of extraction gave adequate color reduction.

A DOUBLE-COUNTER ROTATING-HEAD MECHANICAL SUGAR BEET THINNER

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IN HARVESTED ACREAGE, Michigan ranks third among the states producing sugar beets, with an average of 91,000 acres harvested annually during the period 1938-1947. (1). In the production of sugar beets are two peak periods of high hand labor requirements. The first comes in May and June for weeding and thinning, and the second comes in October and November for harvesting. The mechanical beet harvester, since its introduction 9 years ago, has rapidly displaced hand labor for harvesting. Approximately 62 percent of the 1951 Michigan sugar beet acreage was mechanically harvested.

The traditional practice in sugar beet production has been to seed at high rates, then follow with hoe and finger thinning to reduce the stand to single plants uniformly spaced. With the mechanization that has taken place in agriculture during the past 10 years, the seedbed preparation and planting operations can be accomplished within just a few days after the soil becomes dry enough to till. Consequently, a major part of the crop is ready for thinning and weeding at about the same time. This has created a demand for a large supply of labor to accomplish this when the seedlings are at optimum size for best results. A declining labor supply has resulted in increased demand on the engineers to develop a machine for thinning and weeding.

Mechanical blockers have been used, but the results have not been completely satisfactory. Blockers cut strips of beets and weeds entirely out of the row at regular intervals, leaving the blocks which may contain beets at the final stand interval. Hand labor is then used to remove the excess beets and weeds from within the block. Both conventional and special machines have been used for blocking. Row-crop cultivators, equipped with weeder blades and disks adjusted to produce a

[1]The studies herein reported were conducted as a cooperative project between the Agricultural Engineering Department of Michigan State College and the Division of Farm Machinery, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

ARTICLE 34-49

desired block spacing, have been operated across the rows. Down-the-row blocking has been accomplished with mechanical cotton choppers and with experimental chemical and flame blockers. Mechanically made blocks may not contain beets because the machine does not automatically adjust itself to irregularities of stand in the row.

Tests were made in 1947 on chemical, mechanical, and flame down-the-row blockers (2). The labor requirements for hand thinning machine-blocked beets were compared with completely hand-thinned check plots. The average hand labor requirement for thinning blocked beets was 80 percent of the labor required for completely hand-thinned beets. Final stand counts indicated that the plant population per 100 feet of row of hand-thinned machine-blocked beets was 79 percent of the stand in the completely hand-thinned check plots.

MECHANICAL RANDOM STAND REDUCTION AND WEEDING

Among the conventional implements that have been used for random stand reduction are pencil weeders, rotary hoes, spike tooth harrows, and side delivery rakes.

A commercial machine that has been developed for down-the-row operation is shown in Fig. 1. This type of machine does a more uniform job of thinning and weeding than can be readily accomplished with implements that are dragged across the row. More satisfactory depth control is possible when down-the-row equipment is used.

The effectiveness of random thinners is modified by the size of beets, soil structure and moisture, and adjustment of the working depth of the tine. The spring-tine unit has given best results when used on small beets in the two- to four-leaf stage. As the beets become larger, the percentage of beets and weeds removed by the spring tine is reduced. When the beets are too large for satisfactory tine thinning, the tine heads should be replaced with positive cutting knife heads.

In operation the tines are comparable to the spokes of a rimless wheel cutting across the row several times per foot of forward travel to cut out beets and weeds (Fig. 1). The small blocks that are formed in this way can be further thinned by additional trips over the field with the thinner or by laborers using long-handled hoes.

The results with random stand reduction methods have been more satisfactory than have been obtained with blockers which make a wider cut across the crop row. In the past, the concept of a correctly thinned field has been that there must be single beets at regularly spaced inter-

Fig. 1. A commercial four-row, ground driven, trailer type, row crop thinner and weeder. The 14 spring tines on each of the rotating heads sweep across the row at an angle as the machine is pulled down the row. The tines scratch across the row at 2½-inch intervals. Knife equipped heads, which have a positive cutting action, can be substituted for removing larger beets.

vals. To accept random stand reduction requires a change of the concept of satisfactory thinning to that of a specified number of plants per 100 feet of row. Gaps between plants that are greater than the average desired can be compensated for by the hand thinners leaving areas of more closely spaced beets and some doubles. Tests (3, 4, 5), have shown that up to 20 percent doubles do not affect the yield, and equal yields have been obtained when the spacings have varied from 12 to 20 inches in 28-inch rows.

AN EXPERIMENTAL SUGAR BEET STAND REDUCER AND WEEDER

A two-row machine was designed and constructed in 1950 by the author for thinning and weeding. It varies from the conventional commercial machine in that the tines, on two heads rotating in opposite directions to each other, are used to thin a row. The tines cut an X-shaped pattern in the row, as shown in Fig. 2.

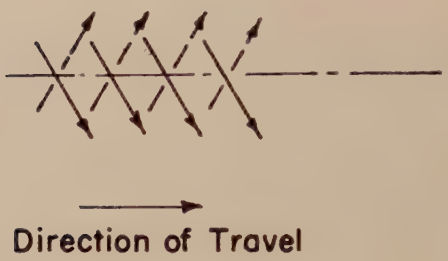

Fig. 2. Pattern of cuts made by counter-rotating heads of experimental thinner. The axes of rotation of the two heads are offset on each side of row. The direction of movement of the two sets of tines as they cross the row is shown by the arrows.

Fig. 3. Tractor mounted, two-row, power-take-off driven, experimental sugar beet stand reducer with two counter-rotating, spring-tine heads on each row. The manner in which the unit is driven from the power-take-off of the tractor can be observed at the rear of the tractor. Various combinations of the roller chain sprockets determine the spacing of scratches across the row in a given tractor gear.

The machine provided a flexible unit with which to study the effect of varying the 1) spacing of cut interval across the row, 2) tine tip velocity, 3) depth of tine tip penetration, and 4) type of tine or cutter head used. Tests made in 1950 indicated that the number of trips over the field could be reduced by a half when the experimental machine was compared with the single-head machine.

The machine was built for rigid attachment to the tool bar of a tractor and adjustment to the row profile was permitted by the limited flexibility of the tool bar mounting frame. A second machine was built in 1951 that retained the counter-rotating spring tine thinner heads (Fig. 3). The redesigned depth control and manner of mounting on the tractor proved satisfactory. Details of this machine are shown in Figs. 4, 5, and 6.

Fig. 4. Experimental sugar beet stand reducer in action. The unit is lifted for turning in the field and road travel by raising the tool bar to which it is clamped. The tool bar is raised by a hydraulic control on the tractor. The two front heads rotate in a clockwise direction and the rear ones in the opposite direction.

Fig. 5. Depth gage wheel. The depth gage wheel is attached under the gear case in a position where it runs directly over the row of plants. No injury to the plants was observed and by placing the wheel on the row and between the rotating heads uniform penetration of the soil by the tine tips is obtained. The gage wheels carry only a few pounds of weight, as most of the weight of the floating parts is counter-balanced by an extension spring which can be seen in Fig. 3. The depth gage can be adjusted vertically to control the depth of spring tine penetration of the soil.

RESULTS OF TESTS WITH EXPERIMENTAL STAND REDUCER

Numerous tests were conducted to determine the effects of different adjustments upon the percentage of plants removed. Increasing the number of cuts per foot of row results in more plants being removed. Likewise, increasing the depth of tine penetration of the soil increases the number of plants removed. The operating speed within practicable limits did not appreciably affect the percentage of beets removed. When the plants are small, more of them are removed with a given amount of working than with larger plants. Inasmuch as the action of the spring tines is similar for commercial machines, it is felt that similar results can be achieved with the same amount of thinning action. By going over a field twice with a single-head machine (the second time in the opposite direction from the first time over) the action upon the row of beets is approximately the same as is produced

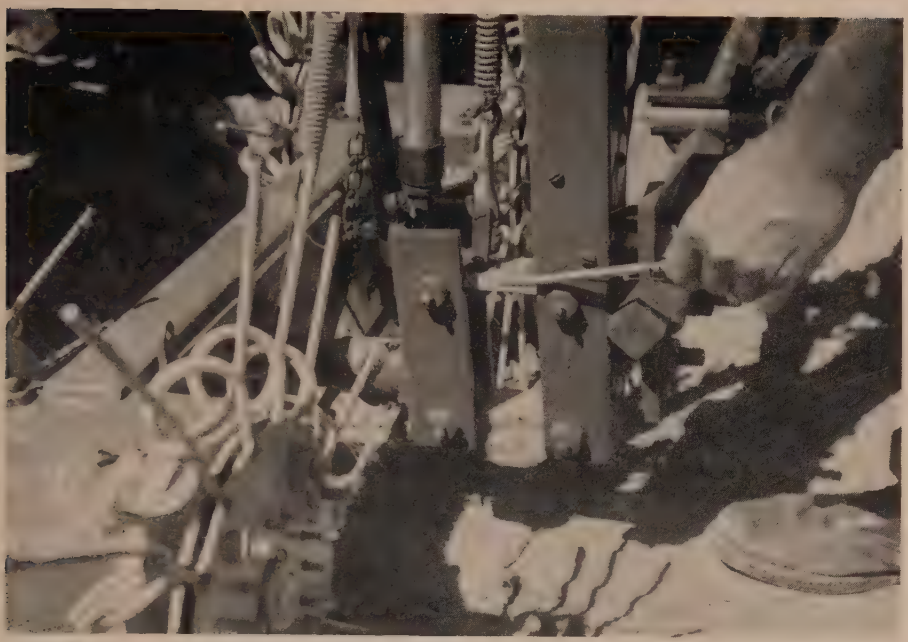

Fig. 6. Parallel linkage allows for vertical adjustments to the row profile. This linkage, together with the pivot about which the body of the unit can rotate within limits, permits each depth gage wheel to follow its row profile. The lower end of the spring which counterbalances part of the weight of the floating parts can be seen attached to the upper parallel link.

in one operation with the experimental machine with two counter-rotating heads on a row.

Since the beet size, soil structure, stand, and moisture content of the soil at the time of thinning vary greatly, it does not appear practicable to attempt to rigidly correlate instructions for machine adjustments with assumed field conditions. Successful operation of mechanical thinners depends to a considerable degree upon the experience, skill, and judgment of the operator.

Both in 1950 and 1951 a series of replicated plots were machine-thinned and time studies were made on the labor required for long-handled hoe thinning following the use of the stand reducer-weeder, as compared with completely hand-thinned check plots. The average of the two years' tests indicated that the machine-thinned plots required 59.8 percent as much labor as the check plots, yielded 74.7 percent as many marketable roots per acre, and 91.0 percent as much tonnage of beets. That the number of marketable roots per acre was greatly less in the machine-thinned plots was due to the inexperience of the thinning labor as to the concept of leaving a certain number of

beets in a given length of row. The reduction in yield of the machine-thinned plots was associated with the lower plant population. In both years the labor was inexperienced with the requirements for leaving a certain number of plants, even though the spacing might be irregular.

As for the tests discussed above, the hand trimming was accomplished before the beets were large enough to suffer from overcrowding. In commercial practice the use of thinners must be considered in light of the fact that there is never enough labor available to hand-thin the entire crop at exactly the right time. By accomplishing partial thinning mechanically at the right time, a delay in hand trimming will not be so serious as when no mechanical thinning is done. Mechanical thinners, therefore, can be used to extend the period over which hand working can be effectively done.

PRACTICES TO INCREASE THE EFFECTIVENESS OF MECHANICAL THINNING

Successful operation of mechanical thinners requires some skill, experience, and judgment on the part of the operator. In addition, the observance of desirable cultural practices will increase the effectiveness of mechanical thinners. Some of these are:

1. Selection of fields with history of good weed control for sugar beets.

2. Reasonably uniform seedbed preparation.

3. Crop rotations and tillage practices to build up and maintain good soil structures.

4. Adjustment of the sugar beet drill for uniform seed distribution and accurate row spacing.

5. Use the mechanical thinner early before the beets and weeds are too large for the spring-tine heads to be effective. If sufficient stand reduction cannot be achieved with the spring-tine heads, use thinner knife heads which are available for commercial sugar beet thinners.

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COMPARATIVE TILLAGE TESTS AT EAST LANSING, MICHIGAN

A PROGRESS REPORT

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DEPARTMENT OF SOIL SCIENCE AND MICHIGAN HYDROLOGIC RESEARCH PROJECT STATION

AN EXPERIMENT comparing conventional moldboard plowing with three variations of the tillage methods known as stubble-mulch farming was undertaken on the Michigan State College Farm at East Lansing in the fall of 1942. This study was instituted because of increasing interest, particularly in the low rainfall areas of the Northern Great Plains Region, in this relatively new form of cultural system. Stubble-mulch farming reduces damage to soil from the impact of raindrops, reduces runoff and erosion, increases infiltration of water, and lessens the cost of fitting the seedbed.

Stubble-mulch tillage methods have one thing in common: Each of the variations in preparing the land leaves a partial or complete mulch or surface covering on the soil. This mulch is composed of organic matter from the preceding crop, and may consist of stubble, straw, stover, weeds, green manure, or cover crops. In this type of tillage the more or less compacted soil may be loosened and allowed to remain in its original position with little or no mixing of the organic matter, as with the subsurface sweep (Fig. 1), or it may be partially inverted and have the organic matter partly incorporated into it, as with the disks, disk plows, or plow with moldboard removed.

This investigation was designed to study and evaluate stubble-mulch tillage practices under the climatic conditions of southern Michigan, where approximately 90 percent of the total tillable acreage is located. The climate during the growing season is characterized by a cold, wet period during April and May, gradually changing to hot and almost subhumid weather in July and August, and then to a cool,

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ARTICLE 34-50

Fig. 1. Sweeps mounted on lister corn planter chassis.

moist season in September and October. The experiment was planned to find to what extent these practices could be fitted into the average farmer's program, and their effect on soil moisture conditions, crop yields, and costs of production. Four methods of tillage were used in preparing the seedbeds: a) conventional plowing, b) plowing with the moldboard removed, c) disking, and d) subsurface tillage with sweeps.

EXPERIMENTAL WORK

Field tests were started on the College Farm in the fall of 1942, and continued until the summer of 1949. They were carried out on a level to gently sloping area of Hillsdale sandy loam, which is a soil of medium acid reaction (pH 6.0). In this instance it contained a low supply of available phosphorous and potassium. A randomized block experiment was set up, using four treatments replicated four times in each block. Four blocks were used, with all crops grown every year.

The basic rotation was: 1) corn, 2)oats, 3) clover, and 4) wheat. The oats were fertilized with 200 pounds of 2-16-8 per acre at planting time, and the wheat with 300 pounds of 3-12-12 per acre. Manure was applied at the rate of 8 tons per acre to the clover and before preparing

the seedbed for wheat. The second-growth clover was left as a green manure crop.

TILLAGE METHODS

The four methods of tillage compared in this experiment were:

1) Normal tillage (Fig. 3) in which the land was plowed with a moldboard plow for corn, oats, and wheat. Supplemental fitting consisted of disking with tandem disks, harrowing with a spring-tooth harrow, and cultipacking;

2) Disk tillage (Fig. 2) in which the crop residues and stubble were mixed into the surface soil with a double tandem disk. The land was disked for corn, oats, and wheat. Supplemental fitting consisted of packing with a treader (3);

3) Subsurface tillage (Fig. 4) in which the land was prepared with subsurface sweeps. These sweeps were adjusted to cut approximately 3 inches deep the first operation and 6 inches deep the second operation, 2 weeks later. Supplemental fitting of the seedbed consisted of packing with a treader, and

4) Plowing with the moldboard removed from the plow (Fig. 3) so as to partially mix the crop residue with the surface soil. Supplemental fitting consisted of disking, harrowing, and cultipacking.

NEW EQUIPMENT USED

The two pieces of equipment used in this test which are not commonly used in Michigan were the V-shaped subsurface sweeps and the treader.

Two 42-inch V-shaped sweeps were used; they were mounted on a John Deere lister corn planter chassis and had a total cutting width of 7 feet (Fig. 1). Since this implement works beneath the surface of the soil it is classed as a subsurface tiller. The soil is lifted slightly as it moves over the blades, causing some shearing and crumbling. As the soil drops behind the blade more pulverizing action is produced.

The treader, as designated by Duley and Russell (5), is a specially constructed rotary hoe with the wheels reversed so as to produce a packing effect. The pronged wheels of the treader penetrate the mulch and pack the soil from the bottom, making a firm connection between the subsoil and the surface soil. This packing is usually necessary before small grains can be planted in stubble-mulch farming.

Fig. 2. Plowed. Disked. Fitted with sweeps.

Fig. 3. Plowed without moldboard. Plowed. Fitted with sweeps.

RESULTS

Corn, oats, clover hay, and wheat were grown and harvested on these plots from 1943 to 1948, inclusive. The yields obtained are given in Tables 1, 2, 3, and 4. It was generally noted that production costs were decreased through the use of stubble-mulch tillage practices.

Fig. 4. Plowed. Fitted with sweeps. Disked.

TABLE 1—Effect of different methods of tillage on yield of corn

Year	Grain—bushels per acre				Stover—pounds per acre			
	Plow	Disk	Sweeps	Plow—no moldboard	Plow	Disk	Sweeps	Plow—no moldboard
1943.....	33.9	36.7	32.4	22.3	3,645	3,765	3,345	2,575
1944.....	12.2	9.7	15.0	14.2	3,821	2,399	2,981	2,765
1945.....	28.6	37.5	29.7	29.4	3,099	3,573	2,646	2,686
1946.....	11.7	11.1	8.1	12.2	2,101	1,987	2,087	2,051
1947.....	22.3	25.9	26.1	27.2	2,510	2,915	2,308	2,506
1948.....	31.7	42.9	25.4	27.4	5,112	4,351	4,460	4,157
Total.....	140.4	163.8	136.7	132.7	20,288	18,990	17,827	16,740
Mean.....	23.4	27.3	22.8	22.1	3,381	3,165	2,971	2,790

Difference required for significance—2.02 bushels.

The average annual yield of corn grain produced on the plots fitted with disks was significantly greater by approximately 4 bushels an acre than that on the other plots for the 6-year period. The next highest yields were produced on the plots which were plowed and fitted in the normal way. There was no significant difference in yield between plots plowed and fitted in the normal way and those plowed and fitted with the sweeps and with the moldboard removed, although the latter two practices gave slightly lower yields. It might be generally stated that corn yields from stubble-mulch practices were equivalent or superior to those obtained with conventional tillage methods.

TABLE 2—Effect of different methods of tillage on the yield of oats

Year	Grain—bushels per acre				Straw—pounds per acre			
	Plow	Disk	Sweeps	Plow—no moldboard	Plow	Disk	Sweeps	Plow—no moldboard
1943	51.1	14.8	21.0	32.9	2,550	2,331	2,172	1,668
1944	39.9	36.9	38.4	36.8	1,425	1,453	1,730	1,636
1945	51.1	52.5	49.9	55.6	2,962	2,546	2,584	2,891
1946	78.6	64.8	61.6	70.1	2,685	2,271	1,999	2,511
1947	70.0	69.9	64.4	64.0	2,595	2,558	2,638	2,525
1948	63.5	52.5	32.3	49.3	1,904	1,590	1,209	1,469
Total	354.2	291.4	267.6	308.7	14,121	12,749	12,332	12,700
Mean	59.0	48.6	44.9	51.5	2,354	2,125	2,055	2,117

Difference required for significance—3.6 bushels.

The average yield of oats on the clean-plowed plots was significantly higher than that of any of the stubble-mulched plots; that of the plots which were plowed with the moldboard was higher than the yield on the disked plots; and the yield of the disked plots was higher than that of the plots fitted with the sweeps.

TABLE 3—Effect of different methods of tillage on yield of clover hay

Year	Clover hay—pounds per acre			
	Plow	Disk	Sweeps	Plow—no moldboard
1944	3,450	2,972	3,215	3,399
1945	3,207	3,585	2,911	2,974
1946	3,061	2,821	2,968	3,243
1948	3,278	3,008	3,962	3,093
1949	2,355	2,505	2,578	2,614
Total	15,351	14,891	15,634	15,323
Mean	3,070	2,980	3,127	3,065

Difference required for significance—632 pounds.

The yields of clover hay were uniform on all of the plots. There was no significant difference in the yields. Equally good seedings were obtained with stubble-mulch and normal plow tillage.

Two factors which contributed to the better production of crops on the land plowed and fitted in the normal way were better control of weeds and generally greater availability of plant nutrients.

The average yield of wheat on the plots which were plowed and fitted in the normal way was significantly higher than the yields from the plots on which other methods of tillage were used. The clean-plowed plots produced an average annual yield of approximately 8 bushels more wheat an acre than did the other plots, or 48 bushels an

acre more for the 6-year period. There was no significant difference between the yields of wheat on the plots fitted with sweeps and disks. The yields from the plots plowed with the mold-board removed were slightly larger than those from the disked plots and the plots fitted with sweeps, but not so high as those from the plots which were plowed with the moldboard plow.

TABLE 4—The effect of different methods of tillage on yields of wheat

Year	Grain—bushels per acre				Straw—pounds per acre			
	Plow	Disk	Sweeps	Plow—no moldboard	Plow	Disk	Sweeps	Plow—no moldboard
1943.....	27.8	21.1	19.8	24.5	3,093	2,351	2,479	2,664
1944.....	39.5	37.7	37.4	36.6	4,284	4,347	4,129	4,268
1945.....	48.5	43.5	41.0	46.9	6,165	4,714	4,586	5,432
1946.....	46.1	35.2	33.1	41.5	4,342	3,390	3,363	4,058
1947.....	51.1	40.9	45.1	44.3	4,842	3,590	4,397	4,294
1948.....	28.2	13.1	16.0	11.9	3,096	3,046	3,009	3,459
Total.....	241.2	191.5	192.4	205.7	25,822	21,438	21,963	24,180
Mean.....	40.2	31.9	32.1	34.3	4,304	3,573	3,661	4,030

Difference required for significance—2.06 bushels an acre.

WEEDS

Volunteer rye interfered with the growth of wheat in 1943 (wheat had been planted in rye stubble at the beginning of the experiment in the fall of 1942) on the stubble-mulched plots, whereas the normally plowed plot was free of rye. The weed population in the wheat increased yearly on the stubble-mulched plots until it reached a climax in 1948, when downy bromegrass completely dominated all the stubble-mulched plots, but a comparatively weed-free crop was grown on the normally plowed plots.

Yields of oats were seriously impaired by weeds on the disked plots and those receiving subsurface tillage with sweeps in 1943. The weed population was progressively higher each year in the stubble-mulched plots than in the clean-plowed plots.

One of the most troublesome problems in growing corn on the stubble-mulched plots was the failure of these methods of tillage to control weeds. Volunteer red clover, quackgrass, dandelions, and annual weeds were not subdued in the preparation of the land for planting corn but grew so vigorously that it was difficult to find the small corn plants at the first cultivation. However, the excessive growth of weeds had no significantly bad effect on corn yields, which were approximately 12 percent higher from the disked than from the plowed plots.

TABLE 5—Effect of different methods of tillage on the availability of plant nutrients as indicated by tissue tests and plant conditions

Date	Crop	Tillage	Tissue test*					Plant conditions
			NO_3	P	K	Ca	Mg	
June 15, '43	Corn leaves	Plow	B1	2.5	20			Yellow-nitrate deficiency; stunted growth
		Disk	10	2.5	10			Dark green—vigorous growth
Aug. 28, '43	Corn stalks	Plow	5	2.5	40			Dark green—vigorous growth
		Disk	10	2.5	20			Dark green—potassium deficiency
		Sweeps	5	2.5	20			Light green—severe potassium deficiency
		Plow—no moldboard	5	2.5	20			Light green—slight potassium deficiency
June 14, '44	Corn leaves	Plow	10	2.5	40	100	6	Dark green—vigorous growth
		Disk	10	2.5	20	100	4	Light green—potassium deficiency
		Sweeps	5	1.0	20	100	3	Light green—nitrogen and potassium deficiency
		Plow—no moldboard	5	2.5	20	100	5	Light green—potassium deficiency
July 10, '44	Corn leaves	Plow	25	10	200	150	7	Dark green—vigorous growth
		Disk	25	10	50	150	3	Light green—potassium deficiency
		Sweeps	5	10	75	150	3	Light green—potassium deficiency
		Plow—no moldboard	10	10	100	150	3	Green—growth good
Aug. 25, '44	Corn leaves	Plow	3	5	100	100	7	Dark green—vigorous growth
		Disk	3	5	20	150	3	Potassium deficiency
		Sweeps	3	2.5	50	100	3	Slight potassium deficiency
		Plow—no moldboard	3	2.5	50	100	3	Slight potassium deficiency
Aug. 25, '44	Corn stalks	Plow	25	5	150	100	7	Dark green—growth vigorous
		Disk	20	2.5	25	50	3	Potassium deficiency
		Sweeps	3	2.5	50	50	3	Slight potassium deficiency
		Plow—no moldboard	20	2.5	50	50	5	Dark green—good growth
Apr. 25, '46	Wheat leaves	Plow	25	5	40			Dark green—vigorous growth
		Disk	B1	5	20			Yellowish green—stunted
		Sweeps	B1	5	20			Yellowish green—stunted
May 5, '46	Oats leaves	Plow	30	5	20			Dark green—vigorous growth
		Disk	B1	5	20			Yellowish green—stunted
		Sweeps	B1	5	20			Yellowish green—stunted

*Tissue tests were made with the reagents of this Spurway Simplex Soil Testing System. One-half teaspoonful of finely chopped plant material was made up to 13.5 cc. with distilled water and 5 drops of 1-4 acetic acid (No. 1 reagent) solution. One-fourth teaspoonful of powdered charcoal was added to clarify the extract. Results are given as ppm. in the extracting solution.

AVAILABILITY OF PLANT NUTRIENTS

WHEAT

The effect of the different tillage methods on the availability of plant nutrients, as indicated by the growth conditions of the plants and by chemical tissue tests, is shown in Table 5. These were spot checks made when plant symptoms indicated differences in the nutrition of the plants from the various plots.

The first indication in this experiment that tillage influenced the availability of any of the plant nutrients was seen on the wheat in the early spring of 1943. The wheat on the stubble-mulch plots—especially

those tilled with the sweeps—came through the winter in a more healthy, vigorous condition than that on the plowed plots. It had a dark green color and grew vigorously as soon as the soil warmed in the spring; however, the wheat on the plowed plots was very yellow and grew slowly. Tissue tests showed high nitrate content in the leaves of the wheat on the stubble-mulch plots, but a low content in those from the plowed plots. This advantage was largely overcome before midseason, owing to weed competition and a reversal of the nitrate conditions later in the spring. No differences in nitrogen availability, as indicated by the growth of the wheat, were noticeable in the spring of 1944. However, in each of the following years the wheat grown on the stubble-mulched plots—especially those disked and subsurface tilled with sweeps—was light yellowish-green and showed nitrogen deficiency symptoms early in the spring; whereas, the wheat grown on the clean-plowed plots maintained a dark green, healthy color and made vigorous growth. Tissue tests confirmed this diagnosis.

OATS

Oats grown on stubble-mulched plots showed serious nitrogen deficiency symptoms in the early spring of 1943, 1946, and 1948, as did wheat. The oats on these plots were yellowish-green and grew slowly. Tissue tests indicated low nitrate content in the retarded plants. The oats grown on the plowed plots maintained a dark green color and grew vigorously. Tissue tests showed a high nitrate content. There was but little difference in the growth of the oats on the various plots in 1944, 1945, and 1947, and tissue tests showed no marked differences in the nitrate content of the oats from the different plots.

CORN

Corn planted in May 1943, germinated evenly and grew uniformly until it was about 3 inches tall. Shortly after the corn was cultivated the first time, there was a heavy rainfall, amounting to 4.2 inches in 2 hours, followed by several days of cold weather. The corn on the plowed plots turned yellow during this period and grew very slowly, but that on the stubble-mulched plots, especially that on the disked plots, remained dark green and grew vigorously. Tissue tests showed low nitrate supplies in the former and abundant supplies in the latter. On July 1 the corn on the disked plots was approximately 2½ feet in height and that on the plowed plots was only 18 inches high; however, at this time the nitrogen deficiency symptoms had disappeared and

the leaves of the corn on the plowed plots were dark green, and the plants were growing vigorously.

During August and September of 1943 the corn on the plowed plots was dark green, whereas that on the stubble-mulched plots began to die back from the tips of the leaves and showed characteristic potash deficiency symptoms. Tissue tests showed the corn on the plowed plots contained a much larger supply of potash than that growing on the stubble-mulched plots.

The corn on the clean-plowed plots was darker green than that on the stubble-mulched plots from the beginning to the end of the season in 1944. No nitrogen deficiency was noted except on plots fitted with sweeps. Potash deficiency symptoms were noticeable on the corn from all of the stubble-mulched plots. The deficiency was greatest in the corn on the disked plots and intermediate in that on the plots plowed with the moldboard removed from the plow. There were no potash deficiency symptoms on the corn on the normally plowed plots. Plant tissue tests on June 14, July 10, and August 25 confirmed the symptomatic diagnosis.

Similar conditions were found in 1946, 1947, and 1948. Corn on the plots plowed in a normal way exhibited signs of nitrogen hunger in early June. The plants were yellowish-green, and tissue tests showed the plants to contain very small amounts of available nitrogen. Later in the season, corn growing on the plots which were fitted by disking grew vigorously and was dark green. Tissue tests showed a high content of available nitrogen. However, the nitrogen deficiency symptoms soon disappeared from the corn on the plowed plots, and tissue tests made later showed a high content of available nitrogen in the corn plants on these plots.

As in 1943 and other years, severe potash deficiency symptoms developed on the corn in the stubble-mulched plots during August and September, whereas corn growing on the land plowed with the moldboard plow showed no potash deficiency symptoms but developed and maintained a dark green color the remainder of the season. Tissue tests indicated ample supply of available potash and fair nitrogen supply in the plants.

INFILTRATION

Stubble-mulch increased infiltration of water into the soil. However, this is advantageous only when the water-holding capacity of the soil has not been satisfied. The soil is usually saturated in the early

spring when farmers are fitting land for oats and corn in Michigan. Inducing infiltration of more water into the soil at this time merely delays planting. Plots fitted with the sweeps remained too wet to work a week to 10 days after it was possible to get on the other plots with implements. However, this ability of stubble-mulch practices to increase infiltration may be of great value in areas of low rainfall. Tests at East Lansing show that the average annual precipitation of 31.43 inches is reduced by runoff from conventionally tilled areas to 27.02 inches, which is entirely too close to the actual water requirements of the plant for consistent optimum development.

EROSION

Stubble-mulch decreased erosion losses. The blocks of plots sloped slightly from west to east, with a small drainage way in one block. During periods of heavy rainfall considerable water flowed over this area. Whenever this water washed over a clean-plowed plot considerable soil was carried from it. The soil was filtered out of the moving water as it crossed the next stubble-mulched plot.

STUBBLE-MULCH TILLAGE IN MICHIGAN TODAY

Certain modified stubble-mulch systems of farming are in common use in Michigan. One of these is the practice of disking corn stubble in preparing the seedbed for oats in the spring, although the foregoing experiments indicate plowing will, in general, give higher average acre yields over a long period of years. However, the speed with which corn stubble land can be fitted by disking in the spring and the savings in labor and power will in many cases offset the difference in yield.

Many farmers use field-cultivators to aid in controlling quackgrass. This is especially true in the potato growing sections of the state. Here, fields may be cultivated ten to sixteen times producing a stubble-mulch fallow. Land which has been treated in this manner needs no further tillage, except cultipacking, to fit it for planting grain and cover crops in the fall.

Since nitrogen deficiency on stubble-mulched plots of oats and wheat was an important factor in reducing yields, an application of supplemental available nitrogen can easily overcome this drawback. Then too, many soils contain such large supplies of available nitrogen that oats are overstimulated in the early stages of growth. The excessive vegetative growth which is produced results in lodging which, in turn, greatly reduces yields. In these instances a practice, like disking,

which may aid in reducing the available nitrogen, would undoubtedly be beneficial.

CONCLUSIONS

This 6-year comparison of conventional tillage practices with stubble-mulch tillage practices at East Lansing demonstrated that, under local conditions, the plow has given generally superior results to those now obtained from other forms of tillage. However, because of some harmful effects of plowing, it is felt that stubble-mulch tillage practices have potential value in Michigan, when suitable weed-control and fertilization practices are developed to offset disadvantages found with these tillage practices.

Normal tillage produced higher yields of wheat and oats than other practices, but stubble-mulch practices gave equivalent or higher yields than normal tillage for corn. Disking produced significantly higher corn yields than all other tillage practices. There was no significant difference between yields of clover hay from any of the four systems of tillage. The weed problem was severe under all stubble-mulch tillage practices, as were plant nutrient availability problems introduced by stubble-mulch practices. It was noted that infiltration of water into the soil was greater with stubble-mulch than with normal tillage, and that erosion losses were smaller.

A review of these results indicates that effective use of stubble-mulch practices in south-central Michigan demands further research. Fertilization practices, developed for normal tillage with the plow, need to be modified so as to provide a more adequate and balanced plant nutrient availability under conditions of increased organic matter in the surface layer of the soil. The increased problem of weed control, introduced by the use of stubble-mulch practices, needs further attention. The use of chemical weed-killers seems to offer the best possibilities at present. A definite program of research involving different times and amounts of fertilizer application, in connection with different weed-killing practices is indicated. The solution of these basic questions is strongly advised before either a complete acceptance, or dismissal of stubble-mulch tillage practices is accomplished. In addition, it is strongly recommended that a further program of research be developed in Michigan which will determine more thoroughly how crop residues should be utilized, their placement, the degree of fineness to which it is advisable to reduce them, and the time and type of supplementary tillage and cultivation practices which should accompany the use of these systems of farming.

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THE CORRELATION OF LABORATORY SCREENING OF TURF FUNGICIDES WITH FIELD RESULTS[1]

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LABORATORY SCREENING commonly precedes field testing of fungicides as an aid in the selection of those deserving further investigation. The increasing incidence and obvious severity of *Helminthosporium* sp. as a pathogen of bent grasses emphasized the importance of screening of established and new materials against this particular pathogen (6). The need for a fungicide for control of this disease has been strikingly shown in the last 2 years. In this state reports have listed 30 percent killing on some bent grass greens, and reports from Texas have indicated a destruction of 90 percent of the bent grass on golf courses. The effect on the host, which is an almost complete killing of very large areas, ranks *Helminthosporium* as an extremely important bent grass parasite. A search of the literature reveals no composite screening work on any of the fungicides used for control of other fungi pathogenic to fine turf. *Gloeocercospora sorghi* (Copper Spot), *Pellicularia filamentosa* (Brown Patch) and *Sclerotinia homeocarpa* (Dollar Spot) were included in these tests to provide a basis for comparison since their control in the field by the commonly used fungicides is well known.

MATERIALS AND METHODS

As non-sporiferous fungi were involved, it was decided to screen the fungicides on the basis of the inhibition of linear growth of the fungus colony in agar plates containing various amounts of the fungicidal materials.

The fungicidal materials chosen were as follows: Acti-dione (Cycloheximide), Cadminate (Cadmium succinate), Calo-clor (mercurous and mercuric chloride), Calo-cure (the mercury chlorides plus a saf-

[1]Contribution from the Department of Botany and Plant Pathology, Michigan State College, 52-6.

ARTICLE 34-51

ening agent), C & C 1025 (copper zinc cadmium mercury chloride),[2] Crag 531 (copper zinc cadmium chromate), Tat-C-Lect (phenyl mercuric acetate) and Vancide 51 (dimethyedithiocarbamic acid plus 2-mercaptobenzothiazole.) Of these, Acti-dione, Calo-cure and Vancide 51 were the relatively new and untested materials, although Acti-dione had been reported to be a promising turf fungicide (6).

The concentrations of fungicides used were 10, 50, 100, 250 and 500 ppm. for Calo-clor, Calo-cure, C & C 1025, Crag 531 and Vancide 51, while concentrations of 1, 5, 10, 25 and 50 ppm. of the Acti-dione, Cadminate and Tat-C-Lect were used for these more active materials.

The medium used was 2-percent malt extract agar. The fungicide, which was not autoclaved, was added to warm, liquid medium and then serially diluted. The resulting volumes were adequate to pour 16 plates, furnishing 4 replicates of each concentration for all 4 of the fungi. Four pathogens were tested against two materials in each series. A separate lot of malt extract was made for each series. Thus, the medium for testing 10 concentrations and the controls was from the same original source.

The plates were seeded with 5 mm. disks taken from 5-day-old plate culture colonies. Four disks were taken on the radius for inclusion in the four plates comprising a replicate. The seeded plates were held at 29-30° C. and linear growth increments recorded at 24-hour intervals. At the conclusion of the test, five concentrations of each of the eight materials had been tested against four organisms.

EXPERIMENTAL RESULTS

Figures 1 through 4 indicate the inhibition by a few selected concentrations of the eight materials.

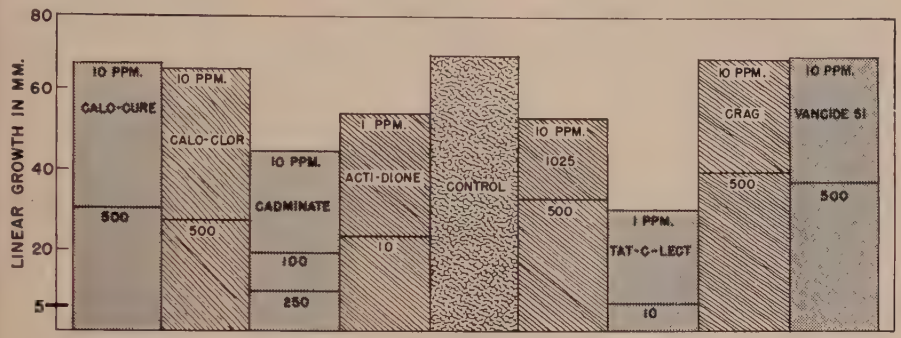
Several interesting facts were brought out by the laboratory testing. *Helminthosporium* sp. (Fig. 2) was found to be the most difficult to inhibit in culture, while the Dollar Spot organism (Fig. 4) was inhibited by very low concentrations of most of the materials. This correlates with field results where Dollar Spot is quite easily controlled, and the *Helminthosporium* is controlled with great difficulty, if at all, by common fungicides.

Also of interest is the stimulated growth of *Helminthosporium* (Fig. 2) by certain concentrations of the mercury compounds and by the C & C 1025. Figure 5 shows the cultural growth in dishes containing

[2]Also referred to as 1025, 1025 Crag, and Crag 1025.

the five concentrations of Calo-clor. Fifty and 100 ppm. stimulated growth of the *Helminthosporium* above that in the control.

In Fig. 1, the Tat-C-Lect is the most efficient in its inhibition of *Gloeocercospora sorghi* at low concentrations. The next most efficient agent is Acti-dione. As a second group, Vancide 51 would be the most efficient, followed by Cadminate and C & C 1025. The other four compounds would rank about the same.



Fungicide	Equivalents	
	Manufacturer's recommendation	P.P.M.
Acti-dione (liquid)	4.0 gm. / 5 gal.—5,000 ft.²	200*
Acti-dione (crystal)	4.0 gm. / 5 gal.—5,000 ft.²	200
Cadminate	0.5 oz. / 9 gal.—1,000 ft.²	250*
Calo-clor	2.0 oz. / 9 gal.—1,000 ft.²	1,660
Calo-cure	.....	.....
Crag 531	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Tat-C-Lect	6.25 oz. /50 gal.—5,000 ft.²	100*
1025 (Crag)	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Vancide 51	.....	3,600*

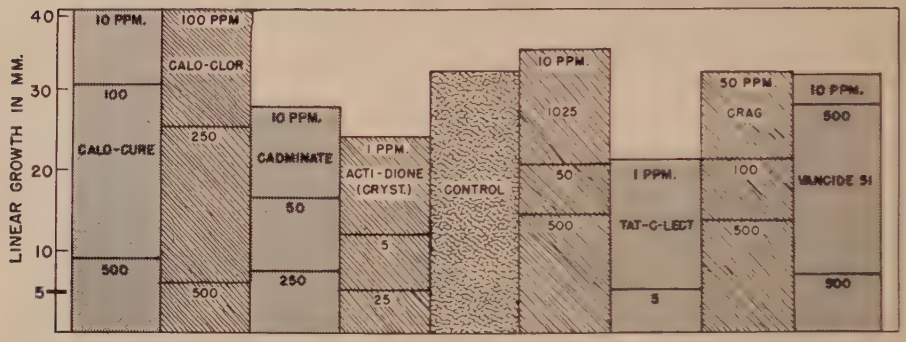
*Active ingredient.

Fig. 1. Growth of *Gloeocercospora sorghi* in medium containing common turf fungicides.

Tat-C-Lect is the only fungicide that at concentrations below 10 ppm. completely inhibited *Helminthosporium* growth. Acti-dione was next in efficiency and Cadminate third. The other compounds caused either a slight inhibition or an actual stimulation at some concentrations.

In Fig. 3 a wider variation of inhibition is noted. Acti-dione inhibits the Brown Patch fungus at a low concentration. Tat-C-Lect and Cad-

minate are next in effectiveness. The mercury compounds are relatively ineffective at these concentrations. The lack of inhibition by the other three compounds indicates that they would be of little value in field applications.



Fungicide	Equivalents	
	Manufacturer's recommendation	P.P.M.
Acti-dione (liquid)	4.0 gm. / 5 gal.—5,000 ft.²	200*
Acti-dione (crystal)	4.0 gm. / 5 gal.—5,000 ft.²	200
Cadminate	0.5 oz. / 9 gal.—1,000 ft.²	250*
Calo-clor	2.0 oz. / 9 gal.—1,000 ft.²	1,660
Calo-cure		
Crag 531	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Tat-C-Lect	6.25 oz. /50 gal.—5,000 ft.²	100*
1025 (Crag)	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Vancide 51		3,600

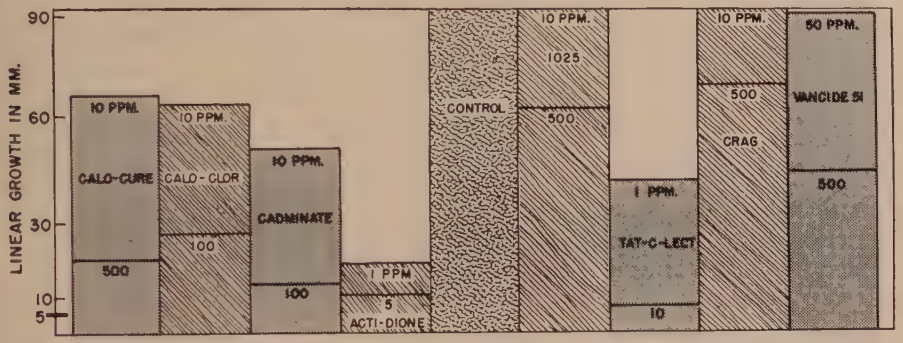
*Active ingredient.

Fig. 2. Growth of *Helminthosporium* Sp. in medium containing common turf fungicides.

Apparent in Fig. 4 is the fact that *Sclerotinia homeocarpa* is easily inhibited by all fungicides except Vancide 51. The first three materials, ranked on the basis of direct inhibition, are: Tat-C-Lect, Acti-dione, and Cadminate. Calo-cure is considered more effective than the Calo-clor since it completely inhibits at 50 ppm. while the Calo-clor does not inhibit completely at this concentration.

Although Figs. 1-4 show the direct inhibition of fungal growth in petri dishes, they do not necessarily indicate the fungicidal efficiency to be expected in the field. As previously mentioned, the concentration of the field application must be taken into account as is done in Tables 1 and 2.

An assignment of an inhibition efficiency rating in the laboratory, and correlation of the activity of the fungicide against one of the fungi in the field are summarized in Table 1. From the laboratory data summarized in Figs. 1-4, the concentration of each material necessary for an inhibition of 50-percent of the check growth was calculated. The foregoing 50-percent inhibition concentration in parts per million was compared with the parts per million normally used in field application in order to set the laboratory-predicted rating listed in the left-hand column of Table 1. The percentage figures used for this rating are listed in Table 2.



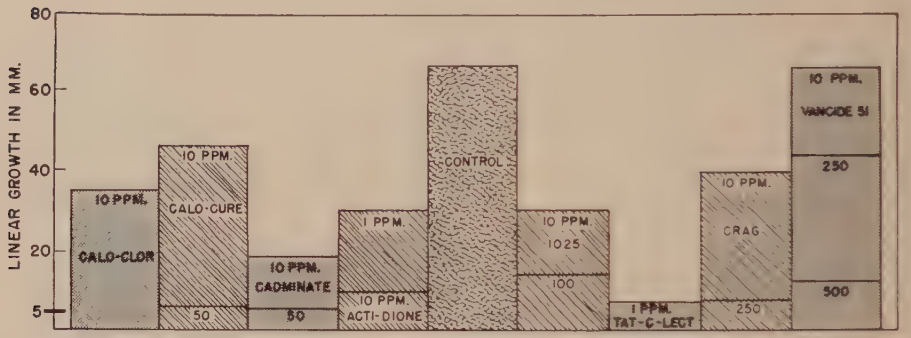
Fungicide	Equivalents	
	Manufacturer's recommendation	P.P.M.
Acti-dione (liquid)	4.0 gm. / 5 gal.—5,000 ft.²	200*
Acti-dione (crystal)	4.0 gm. / 5 gal.—5,000 ft.²	200
Cadminate	0.5 oz. / 9 gal.—1,000 ft.²	250*
Calo-clor	2.0 oz. / 9 gal.—1,000 ft.²	1,660
Calo-cure	.....	.....
Crag 531	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Tat-C-Lect	6.25 oz. /50 gal.—5,000 ft.²	100*
1025 (Crag)	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Vancide 51	.....	3,600

*Active ingredient.

Fig. 3. Growth of *Pellicularia filamentosa* in medium containing common turf fungicides.

A tentative rating of the fungicides, which has been borne out by some field testing, is presented in Table 1. The laboratory rating was partially substantiated by field results on control of Dollar Spot in the field in 1951 (7). In this table, Tat-C-Lect, although very effective in low concentrations in the petri dish tests, is applied in the field at

approximately 100 ppm. in order to be non-phytotoxic and thus did not prove to be the most efficient in the replicated field trials. Except for the Tat-C-Lect rating of number 2 in the laboratory and number 8 in the field, there is a good correlation of laboratory and field rating. The first three compounds, Cadminate, Acti-dione and C & C 1025 then rate 1 - 1, 2 - 2, and 3 - 3 in the laboratory and field, respectively. The predicted ratings in the laboratory of the other materials also closely conform to the field ratings in 1951.



Fungicide	Equivalents	
	Manufacturer's recommendation	P.P.M.
Acti-dione (liquid)	4.0 gm. / 5 gal.—5,000 ft.²	200*
Acti-dione (crystal)	4.0 gm. / 5 gal.—5,000 ft.²	200
Cadminate	0.5 oz. / 9 gal.—1,000 ft.²	250*
Calo-clor	2.0 oz. / 9 gal.—1,000 ft.²	1,660
Calo-cure		
Crag 531	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Tat-C-Lect	6.25 oz. /50 gal.—5,000 ft.²	100*
1025 (Crag)	3.0 oz. / 9 gal.—1,000 ft.²	2,500
Vancide 51		3,600

*Active ingredient.

Fig. 4. Growth of *Sclerotinia homeocarpa* in medium containing common turf fungicides.

Additional substantiation for the relative accuracy of the above-mentioned laboratory method of predicting field performance was found in Rhode Island in 1951 (3), where it was reported that Cadminate and Acti-dione were excellent controls for Dollar Spot.

The laboratory rating of the fungicides on the Brown Patch fungus, although not supported by replicated field results, closely conforms to

TABLE 1—Laboratory rating of turf fungicides

Rating	*	*Sclerotinia homeocarpa*	*Pellicularia filamentosa*	*Helmintho-sporium* Sp.	*Gloeocercospora sorghi*
1	1	Cadminate	Acti-dione	Tat-C-Lect	Tat-C-Lect
2	8	Tat-C-Lect	Tat-C-Lect	Acti-dione	Acti-dione
3	2	Acti-dione	Calo-clor	Vancide 51	Vancide 51
4	3	Crag 1025	Cadminate	Calo-cure	Crag 1025
5	5	Calo-clor	Calo-cure	Crag 531	Calo-clor
6	4	Crag 531	Vancide 51	Crag 1025	Crag 531
7	6	Calo-cure	Crag 1025	Cadminate	Calo-cure
8	7	Vancide 51	Crag 531	Calo-clor	Cadminate

*Rating under field conditions—1951 (*S. Homeocarpa* only).

results in other areas (4). Mercury-containing fungicides have long been effective. The antibiotic Acti-dione, however, gave 50-percent inhibition in petri plates at 0.005-percent of the strength used in the field, while with the Calo-clor 3 percent of the concentration used in the field was necessary for the same inhibition (Table 2). That Acti-dione is efficient in the field is reported by Bishop (1) who found that Acti-dione gave more rapid and efficient control of Brown Patch than Special Semesan, but its residual effect was of shorter duration.

TABLE 2—Percentage of the concentration applied in the field giving 50 percent linear growth inhibition in petri dishes

Fungicide	*G. sorghi*	*Helmintho-sporium* Sp.	*P. filamentosa*	*S. homeocarpa*
Acti-dione.....	2.5	3.5	.005	0.1
Cadminate.....	32	20	8.8	.005
Calo-clor.....	26	21	3	0.9
Calo-cure.....	28	15	13	1.5
C. and C. 1025..	18	18	29	0.3
Crag 531.....	27	17	30	1.0
Tat-C-Lect.....	0.7	2.5	0.3	.01
Vancide 51.....	15	9	25	8

The expected field performance of the various materials for control of *Helminthosporium*, with the exception of Tat-C-Lect, is supported by tests and observations. Of the first three compounds, the Tat-C-Lect was found to have no value as a control (6), and the Vancide 51 has not been employed as a control measure for this disease. Acti-dione, however, has been shown to control the disease in the field when applied to half of a green or to adjacent greens on local

golf courses (6, 7). Acti-dione was also of value in Texas in 1951 for control of *Helminthosporium* on golf course greens (5). Other materials that gave no control in Texas were: Crag 531, Cadminate, Calo-clor, and copper compounds.

As previously mentioned, the mercury-containing Calo-clor actually stimulated *Helminthosporium* growth in petri dishes (Figs. 2 and 5). For activity against *Helminthosporium*, however, the Calo-cure with the safening agent was actually less stimulating than the Calo-clor. In all other cases the Calo-cure rated below the Calo-clor in fungicidal activity.

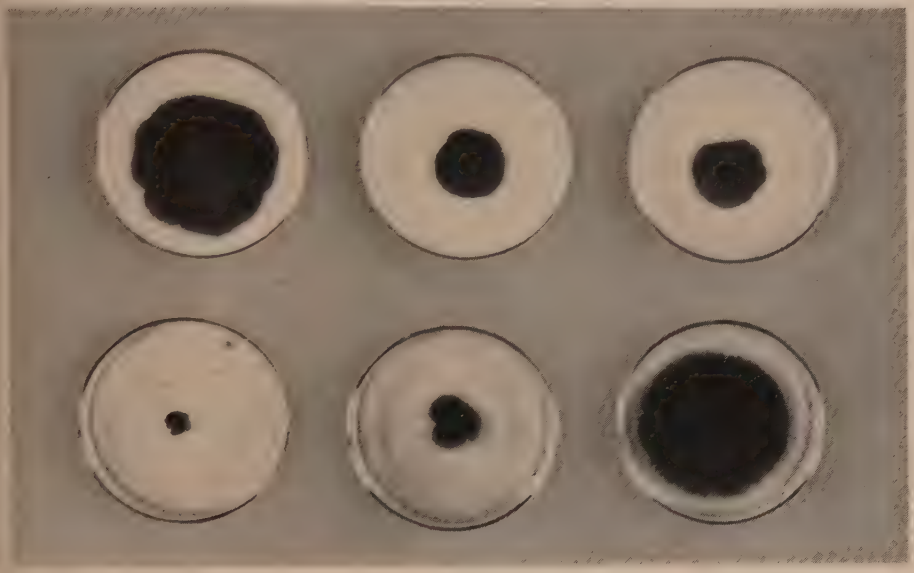
The laboratory rating of fungicides effective against the Copper Spot fungus needs field data for support or rejection. A New Jersey report (2) lists the mercury compounds as being more efficient than cadmium, while data from Rhode Island (4) indicate that the cadmium compounds are the most effective. The disease has not yet been reported in Michigan. By the laboratory rating method, the mercury compounds are rated above Cadminate but below the cadmium-containing Crag 531. Tat-C-Lect and Acti-dione, however, are significantly better than any of the others, on the basis of the laboratory-derived figures. The two compounds seem to merit testing in replicated field plots of bent grass against this disease.

DISCUSSION

In all series, requiring approximately 9 months' time, the growth in the control plates did not vary appreciably. In tests which were repeated, the resulting average growth in the controls did not vary over 2 millimeters from the growth recorded during other trials. It is believed that the use of a large volume of medium, serial dilution, and the radial selection of the inoculum disks contributed to consistency of results.

It is hoped that the data found may be of value for rapid screening of new turf fungicides. Values have been obtained for concentrations necessary to give 50-percent inhibition of fungal growth in petri dishes. Fungicides of proven value give 50-percent inhibition at a very low percentage of the field application (Table 2). Thus, if a new fungicide is tested in the laboratory and the 50-percent inhibition concentration found, a recommendation may be given as to the concentration to test for field control. The percentage of the concentration used in the field to give 50-percent inhibition in the plates should be in a range comparable to proven fungicides. In other cases the amount of fungi-

MERCUROUS AND MERCURIC CHLORIDE



(Top) 100 PPM. 250 PPM. 500 PPM.

(Bottom) 0.0 PPM. 10 PPM. 50 PPM.

Fig. 5. Effect of increasing concentrations of mercury chlorides on the growth of the *Helminthosporium* causing melting out of fine turf.

cide used in the field could possibly be decreased if the 50-percent inhibition value is less than materials giving comparable control. Four to five days of laboratory work could give these answers.

As the Dollar Spot organism is relatively easily controlled on bent grass, the values in Table 2 were not unexpected. The percentage of the concentration used in the field that gave 50-percent inhibition in petri dishes, ranged from 8 percent to 0.005 percent. Seven of the eight compounds gave 50-percent inhibition at concentrations at or below 1.5 percent of the concentration used in the field. Even the Vancide 51 which needed 8 percent of the field concentration for 50-percent petri plate inhibition gave adequate control of Dollar Spot on replicated bent grass plots in 1951.

The inhibition of *Pellicularia filamentosa* showed more specificity. The 50-percent inhibition figures vary from 30 percent of field concentration (by compounds which are not used for Brown Patch control) to 0.005 percent by the Acti-dione. The Calo-clor and the phenyl mercuric acetate compound correlated with field results, since these compounds give good control of Brown Patch when applied to bent grasses.

The percentage figures in Table 2, showing 50 percent inhibition of *Helminthosporium*, are in agreement with results and observations in the field. The common turf fungicides were of no value for control of the *Helminthosporium*. Acti-dione was the only material tested that did control this disease. Even though the Tat-C-Lect gave 50-percent inhibition at a lower percentage than did Acti-dione (2.5 percent compared with 3.5 percent, respectively) the phenyl mercury compound was of little value in field applications. One other material, Vancide 51, indicated value for control of the *Helminthosporium*.

The Copper Spot organism (*G. sorghi*) also exhibited considerable resistance to many of the fungicides. As shown in Table 2, Tat-C-Lect and Acti-dione inhibited the fungus at the lowest percentage of the concentration as applied on established turf. Vancide 51 ranked third on the basis of the laboratory testing, although it was but slightly more inhibitory than the C & C 1025.

On the basis of the derived figures (Table 2) it is hoped that subsequent screening of turf fungicides may be initiated in the laboratory. The screening of untried compounds for control of *Helminthosporium*, for instance, should give 50-percent inhibition of the fungus in culture at a percentage approximating the 2.5 percent obtained with Acti-dione which has proven its value in field applications. Or conversely a concentration economically feasible for use should give a 50-percent inhibition at this approximate percentage.

It may also be possible by this method to ascertain whether, and possibly how much, the active ingredient may be reduced in fungicides now in common use. Table 2 would be of value in this instance. A comparison of the percentage figures indicates that the active ingredients of several chemicals could be reduced and still be in a range comparable with the other effective materials, i.e., Acti-dione and Tat-C-Lect in column 4.

SUMMARY AND CONCLUSIONS

The data obtained by screening fungicides for possible use in control of *Helminthosporium* melting-out served not only that end, but brought to light several other interesting facts. Vancide 51 seems to warrant testing under field conditions against *Helminthosporium*. Tat-C-Lect, an excellent inhibiting agent in the laboratory, has proved to be of little value in the field, but Acti-dione has been very effective in controlling this disease under field conditions. The other compounds

tested seem to have little activity against *Helminthosporium* in the laboratory.

The method is consistent, with the exception of the phenyl mercuric acetate, and may be accurate enough to allow prediction of the subsequent field performance. The derived values could also shorten initial laboratory screening work by providing some data to which unknown compounds could be compared.

Utilization of the inhibition values may allow reduction of the amounts of fungicides now in use, and may allow accurate prediction in the laboratory of the concentrations necessary for control in the field.

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MINT RUST AND ITS CONTROL[1]

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DEPARTMENT OF BOTANY AND PLANT PATHOLOGY

THE PRODUCTION of spearmint and peppermint oils is a highly specialized industry restricted to favorable areas in the midwest and on the Pacific Coast. The major plantings of peppermint are in Michigan, Indiana, Oregon and Washington. In Michigan and Indiana mints are grown on muck soils, commonly without irrigation, whereas peppermint is grown on irrigated, mineral soils in Oregon and Washington. The growing of spearmint is restricted mostly to Michigan and Indiana.

Mint rust (*Puccinia menthae*) appeared in peppermint plantings in Columbia County, Oregon, in 1949. By 1950 it had spread to all mint sections in that state and was destructive in Washington. It also appeared in Canada in 1950. Prior to 1951 this disease had not been observed on peppermint in Michigan and Indiana but had, on occasion, been injurious to spearmint. The development of rust in commercial plantings of peppermint in Michigan in 1951 presaged a new disease control problem for the Michigan mint industry. Investigations in the control of this disease are reported in this paper.

DISTRIBUTION

Mint rust is world wide in its distribution. It occurs on many plants other than peppermint and spearmint, all of which, however, belong in the family *Labiatae*. The rust fungus was first described by Persoon in 1801 (4). Its complete life cycle comprises five spore stages, all of which develop on mint. The distribution of the fungus is influenced by the occurrence of physiologic or specialized races, each of which is restricted in its host relationship. Rust has occurred for many years on spearmint in Michigan and Indiana without attacking adjacent plantings of peppermint. The rust is heterothallic, and its autoecious development makes possible the generation of new races on its various host plants.

[1]Contribution from the Department of Botany and Plant Pathology No. 52-7.

ARTICLE 34-52

The initial development of rust on peppermint in Oregon in 1949 and its rapid spread to all mint sections of that state in 1950 are indications that this disease will also spread to all mint sections in Michigan and Indiana, following its appearance in Michigan in 1951.

IMPORTANCE

There are no records of widespread and destructive epidemics of rust on mints in Michigan and Indiana though spearmint has been seriously attacked in seasons favorable for the development of the disease. A good example of the potential destructiveness of the rust is the record of its development in the late-harvested fields of spearmint in Michigan in 1951. The plantings harvested early, that is in late July and early August, were not noticeably affected though rust pustules were detectable on the lower leaves. Weather conditions were especially favorable for a rapid increase of the disease in August; consequently, the latest-harvested fields were severely affected and oil yields greatly reduced. In some seasons earlier attacks of rust make it necessary to harvest fields prematurely to prevent extensive defoliation. Since distilling capacity is limited on mint farms, the plantings are spaced to mature over a period of 4 to 5 weeks. As a consequence, the late-harvested fields may be severely damaged by rust though the early maturing ones are only slightly affected.

Rust has developed to destructive proportions on peppermint in Oregon and Washington where environmental conditions are much more favorable for epidemics than in Michigan. Dietz, Steenland and Horner reported a 25-percent reduction in oil yields in Columbia County, Oregon, because of rust in 1949 (2). Losses as high as 40 percent were reported to the writer from western Washington in 1950. The use of overhead irrigation is a factor contributing to the more favorable conditions for rust infection in Oregon and Washington, but the prevalence of fogs and dews is probably the most critical factor in those sections where the rust has caused the most damage.

Some Michigan plantings of peppermint were so severely rusted in 1951 that oil yields were greatly reduced. Complete defoliation and killing of all top growth occurred in some of the nursery accessions at East Lansing. Experimental plantings of peppermint on mineral soil were badly damaged in some sections of the fields (Fig. 3). In the nursery planting containing 63 accessions, the development of rust varied from none on some plants to complete defoliation of others. The so-called American clone of *Mentha piperita* appeared to be more

resistant than the various clones of the English or Mitcham variety. The variable reactions to rust in this collection of clones of *Mentha piperita* growing in close proximity indicates that there are genetic differences among them, probably traceable to mutational origins.

LIFE HISTORY OF PUCCINIA MENTHAE

Puccinia menthae develops its five spore stages on mint, all of which are functional in Michigan. The teliospores produced in late autumn winter over on infected leaves and stems. (Fig. 1, B). The germinating teliospores produce sporidia which infect young mint

Fig. 1. A—Light brown masses of uredospores of mint rust on the lower surface of Scotch spearmint leaves.

B—Dark brown teliospores appearing in late August in uredinial sori on the lower surface of Scotch spearmint leaf. The teliospores are also produced on infected stems.

shoots either in the soil or after they emerge. The orange-colored pycnial and aecial stages which result from the sporidial infections may be observed on the infected leaves and stems in late May and early June. (Fig. 2, B). The aeciospores are wind disseminated and mostly infect plants close to the source of production, but may be carried to other fields to establish initial infections. Infections by aeciospores eventuate in the uredinial stage of the rust which is the important spore stage for the rapid dissemination of the fungus. The uredospores are produced in light brown, powdery masses on the lower surfaces of the leaves and on the stems (Fig. 1, A). They are produced continuously under favorable weather conditions and are widely dispersed by winds. In seasons when heavy dews and fogs occur frequently, or when rainfall is excessive in July and August, rust may develop rapidly and extensively within a short time, as in 1951. The extent and rate of this increase are determined by the prevailing weather conditions in July and August. Conditions of temperature and moisture which inhibit the deposition of dew are the most influential factors in checking the development of rust.

RESISTANCE AND SUSCEPTIBILITY

Puccinia menthae has been reported on many plants in the family *Labiatae*, but the host range of the fungus in Michigan outside of the genus *Mentha* has not been investigated. Observations for many years, however, have revealed the specialized host relationships of the fungus. Spearmint has rusted consistently in Michigan and Indiana in years favorable for the development of the rust disease, but adjacent plantings of peppermint have remained rust-free. It has long been assumed that this behavior is due to the occurrence of physiologic races of the fungus. In his investigation of rust on greenhouse-grown spearmint in New York, Niederhauser found that the rust was so specialized that it would infect only the species or variety from which the inoculum was taken (3). The rust on spearmint would infect only spearmint. So close, moreover, was this selectivity that the rust collected on wild or escaped spearmint plants would not infect a cultivated clone in the greenhouse. He concluded that *Puccinia menthae* is composed of many phytopathogenic races which are highly selective in their host relationships.

Baxter has reported the identification of 10 races of *Puccinia menthae*. Race 1 infects *Mentha spicata, M. arvensis,* and *M. rotundifolia.* Race 2 infects *Mentha piperita, M. arvensis* and *M. longifolia.*

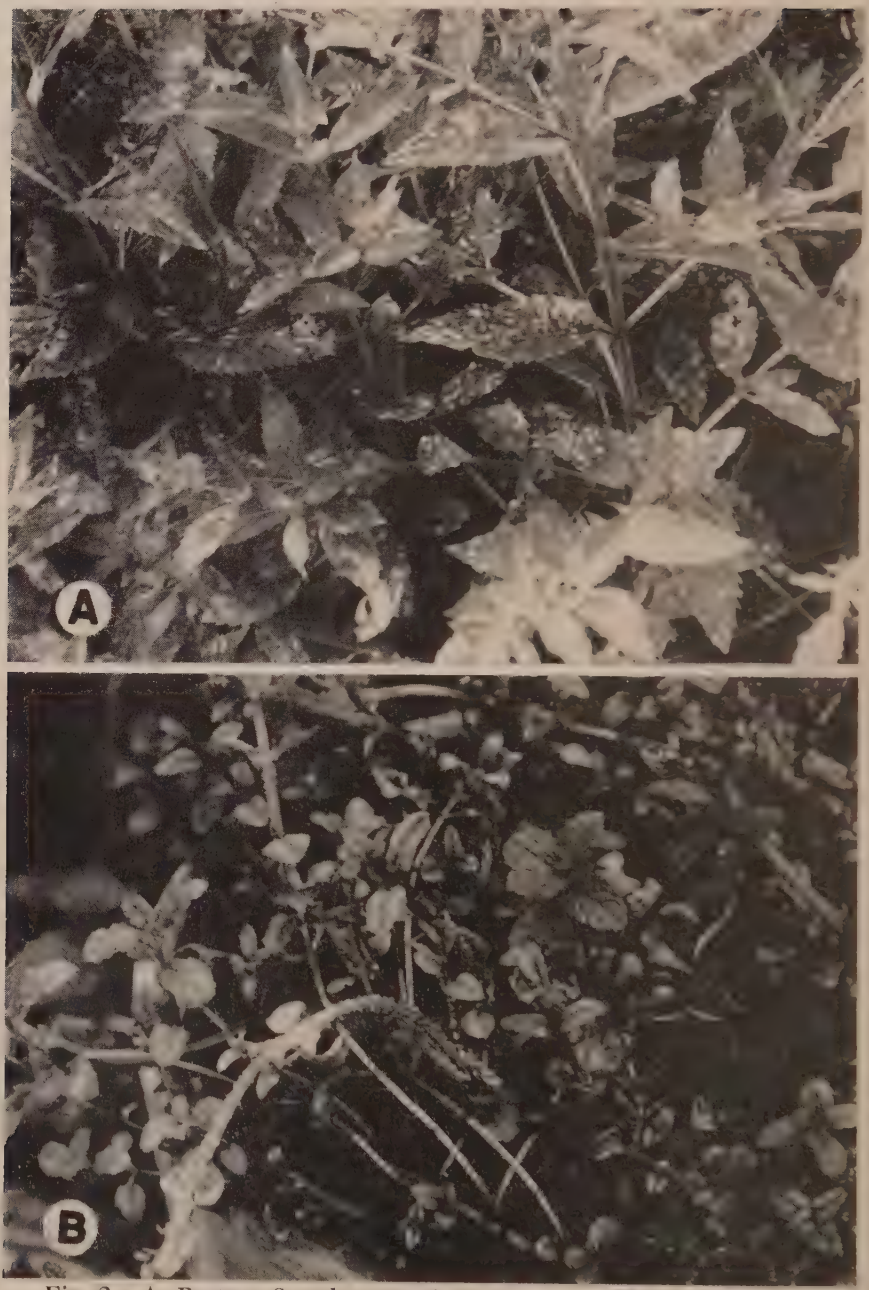

Fig. 2. A—Rust on Scotch spearmint in August. The upper surfaces of infected leaves are spotted yellow. The spores are borne mostly on the lower surfaces.

B—Orange-colored masses of aeciospores on leaves and stems of systemically-infected shoots of Scotch spearmint. Pycnial and aecial sori appear on so-called "bull" shoots which are much thicker than normal ones.

The other eight races are specialized on plants in other genera of the *Labiatae* (1).

Observational evidence indicates that such a highly specialized relationship between the rust fungus and its host plants, as reported by Niederhauser and Baxter, does not exist in Michigan. In connection with breeding work for resistance to Verticillium wilt in peppermint and spearmint, an extensive collection of species, varieties and hybrids of *Mentha* has been maintained for many years. Prior to 1949 this collection of mints was grown on the A. M. Todd Plantation at Mentha, Michigan. For the past 3 years it has been grown at East Lansing. Especial note has been made since 1944 of the development of rust in these plants. The integrity of each clone has been maintained by biennial transplantation to a new site. The plants grow to maturity each year, and observations are made late in the season after rust has attained its maximum development. The disease usually develops more severely in susceptible clones in the nursery than in commercial plantings of mints harvested for oil production.

Records made in 1945 when rust was severe in some of the nursery accessions and in commercial fields of spearmint on the Todd Plantation are shown in Table 1. Only the data on species and varieties are given since none of the hybrid seedlings was affected.

Mentha arvensis v. *piperascens, M. citrata* and four accessions of *M. spicata* were attacked by rust in the nursery in 1945. One spearmint clone, a variety from Kew Gardens, England, was rust-free. The American and Scotch clones of *M. spicata,* including the hairy variety of the Scotch, and an escape variety of spearmint collected in the Berkshire Hills of Massachusetts, were completely defoliated. Several clones of *Mentha piperita,* including the American and Mitcham that had been grown on the Todd Plantation in former years, were rust-free. *Mentha crispa,* as in previous years, was not infected. Six seedlings of this species, which sets seed freely, were also free from rust. *Mentha crispa* is not a pure species since it is heterozygous for many characters and its seedlings vary morphologically and in rust resistance. Segregation of its seedlings usually occurs in the ratio of 3 resistant to 1 susceptible, indicating that rust resistance is conditioned by a single dominant factor. The effect of lethal genes, however, is likely to obscure the true segregation ratios. Thousands of hybrid seedlings resulting from crosses between *Mentha piperita* and *M. crispa* have been grown on the Todd Plantation since 1939 and none has rusted. In 1948, 3,500 seedlings out of crosses between *Mentha spicata,* vars.

TABLE 1—Rust reactions in species and varieties of *Mentha* and *Monarda* grown in Mint Nursery at Mentha, Mich., 1945

Species or variety	Rust index*
Mentha piperita, Mitcham	−
Mentha piperita, American	−
Mentha sylvestris	−
Mentha sylvestris v. *variegata*	−
Mentha rotundifolia	−
Mentha rubra	−
Mentha citrata	++
Mentha arvensis v. *piperascens*	++++
Mentha pulegium	−
Mentha gentilis	−
Mentha cardiaca	−
Mentha spicata, American	+++++
Mentha spicata, Scotch	D
Mentha spicata, Harry Scotch	D
Mentha spicata, Escape, Berkshire Hills, Mass.	+++++
Mentha spicata, Kew Gardens, England	−
Mentha crispa	−
Mentha crispa, Six seedlings	−
Monarda fistulosa	++

*Rust index:
− rust-free
+ slightly rusted
+++++ severe defoliation
D all top growth killed by rust

Scotch and American, were grown at Mentha. One-fourth of these seedlings were attacked by rust confirming the heterozygous nature of *M. crispa* and the dominance of rust resistance in this clonal species.

The mint nursery was moved to East Lansing in 1949, but the season was very dry and rust developed very slightly and only in the most susceptible accessions. It developed very severely, however, in 1950 but only the species and varieties that had rusted in previous years at Mentha were affected. No accession of *Mentha piperita* was infected, and several clones of *M. spicata* added to the collection since 1945 were also rust-free. The rust reactions of the plants in the nursery at East Lansing appeared to be the same as they had been for many years on the Todd Plantation.

Rust developed destructively in several commercial plantings of peppermint in Michigan in 1951 and in the mint nursery at East Lansing. It was observed in Muskegon, Newaygo and Ingham Counties. The Muskegon and Newaygo County outbreaks are probably traceable to a common source of inoculum since these plantings were not separated sufficiently to eliminate the possibility of spore dispersal from one area to the other. The simultaneous development of rust in some fields

of peppermint growing in the Chandler Marsh near East Lansing and in the mint nursery may also have originated from a common source of spore dispersal. These plantings are separated by a distance of about 6 miles. Rust did not attack any of the peppermint clones in 1950 when some of the spearmints were seriously affected. The occurrence, therefore, of the rust on peppermint accessions in 1951 indicates that the disease originated from a source of spore dispersal that was not active in 1950. This source could have been the Chandler Marsh infection center or one dispersing spores to both locations.

Fig. 3. Rust on English peppermint at East Lansing, 1951. The appearance of rust in this planting and in commercial fields 6 miles away was the first observed outbreak of this disease in Michigan. In the central foreground the plants are so severely rusted that all top growth has been killed.

Records were taken in September and in late October of the rust reactions of the 63 accessions in the mint nursery. Some of the plants that were rust-free in September were rusted when examined in late

October. The October records represent the maximum development of rust in 1951 since the plants were damaged by freezing temperatures soon after the disease readings were made. The reactions of the nursery accessions to rust infection in 1950 and 1951 are shown in Table 2.

A comparison of the species, varieties and hybrids affected with rust in 1950 and 1951 reveals the greatly extended host range of the disease in 1951. Whereas only 10 of the 62 accessions were rusted in 1950, 46 of the 63 plants in the nursery in 1951 were attacked. The host range was extended to include all clones of *Mentha piperita*, 5 clones of *M. spicata* that had not rusted in 1950, *M. gentilis*, *M. sylvestris* v. *variegata*, an unidentified species from Tennessee, 4 polyploid seedlings of *M. piperita* and two wilt-resistant seedlings from crosses between *Mentha piperita* and *M. crispa*.

Of especial interest were the reactions of the accessions of *Mentha spicata* and of *M. piperita*. Baxter reported that race 1 of *Puccinia menthae* infects *Mentha spicata*, *M. arvensis* and *M. rotundifolia*. In the mint nursery at Mentha in 1945 and 1948 and at East Lansing in 1950 and 1951, all years when rust was epidemic in commercial plant-

TABLE 2—Reactions to rust (*Puccinia menthae*) of species, varieties and hybrids of *Mentha* in the Mint Nursery at East Lansing, Michigan, 1950 and 1951

Accession No.	Identification and source	Rust index*	
		1950	1951
1	*M. spicata*, University of Washington	−	+
2	*M. spicata*, Unknown	−	+
3	*M. spicata*, Garden Plant, California	−	+
4	*M. spicata*, Unknown	−	+
5	*M. spicata*, Common American	+++	++++
6	*M. spicata*, Escape, Berkshire Hills, Massachusetts	+++	D
7	*M. spicata*, Escape, Mentha, Michigan	+++	+++++
8	*M. spicata*, Escape, Mentha, Michigan	−	+
9	*M. spicata*, Scotch	++++	D
10	*M. spicata*, American	++++	D
11	*M. spicata*, Washington State College	+	++++
12	*M. spicata*, Kew Gardens	−	−
13	*M. rotundifolia*	−	−
14	*M. sylvestris*	−	−
15	*M. sylvestris* v. *canadensis*	−	−
16	*M. sylvestris* v. *variegata*	−	+
17	*M. cardiaca*, Highland, Michigan	++++	D
18	*M. canadensis*	−	−
19	*M. arvensis* v. *piperascens*, U. S. D. A., Beltsville, Md.	++	++
20	*M. arvensis* v. *piperascens*, Baraboo, Wisconsin	+	D

TABLE 2—*Continued*

Accession No.	Identification and source	Rust index*	
		1950	1951
21	*M. arvensis* v. *piperascens*, California	+	+++++
22	*M. rubra*	−	−
23	*M. pulegium*	−	−
24	*M. gentilis*, Mentha, Michigan	−	−
25	*M. gentilis*, U. S. D. A.	−	++
26	*M. niliaca*, U. S. D. A.	−	−
27	*M.* species, unidentified	−	−
28	*M. citrata*, University of Washington	−	+
29	*M.* species, unidentified, Tennessee	−	+
30	*M.* species, morphologically like *M. piperita* but not in odor	−	−
31	*M. piperita*, unknown	−	++
32	*M. piperita*, Ann Arbor	−	++
33	*M. piperita*, unknown	−	++
34	*M. piperita*, American, Williams, Michigan	−	+
35	*M. piperita*, Kennewick, Washington	−	+++++
36	*M. piperita*, American, near Mentha	−	++
37	*M. piperita*, Mitcham, domestic	−	++++
38	*M. piperita*, Mitcham, England, 1949	−	+++
39	*M. piperita*, Cedar Lake, Indiana	−	+++
40	*M. piperita*, Wm. Gehring, Indiana	−	+++++
41	*M. piperita*, Los Angeles, California, originally from Clinton County, Michigan	−	+++++
42	*M. piperita*, Polyploid clone	−	+++++
43	*M. crispa*, Kew Gardens	−	−
44	*M.* species, unidentified, California	−	−
45	X (*M. piperita* X *M. crispa*) seedling	−	+
46	*M. piperita*, polyploid seedling	−	+++++
47	*M. piperita*, polyploid seedling	−	++++
48	*M. piperita*, polyploid seedling	−	+++
49	*M. piperita*, polyploid seedling	−	++++
50	X(*M. piperita* X *M. crispa*) seedling No. 39-08	−	−
51	X (*M. piperita* X *M. crispa*) seedling	−	−
52	X(*M. piperita* X *M. crispa*) seedling	−	−
53	X(*M. piperita* X *M. crispa*) seedling	−	−
54	X(*M. piperita* X *M. crispa*) seedling	−	+
55	X(*M. piperita* X *M. crispa*) seedling	−	−
56	X(*M. piperita* X *M. crispa*) seedling No. 43-12	−	−
57	*M. piperita* (polyploid) X Acc. 50	−	+
58	*M.* species, U. S. P. I. 177465	−	−
59	X[*M. piperita* (polyploid)] X Acc. No. 50	−	+
60	*M.* species, Muskegon, Michigan, 1951		+++++
61	X(*M. piperita* X *M. crispa*) seedling No. 46-24	−	−
62	X(*M. spicata* X *M. crispa*) seedling No. 48-2042	−	−
63	X(*M. spicata* X *M. crispa*) seedling No. 48-2089	−	−

*Rust index:

− rust-free
+ slightly rusted
+++++ severely rusted defoliation
D all top growth killed by rust

ings of spearmint, *M. rotundifolia* was rust-free. In 1951, five clones of *Mentha spicata* that had not rusted in 1950 were lightly infected. Nursery accession No. 12, a spearmint from Kew Gardens, was not affected either in 1950 or 1951. This mint was used for some time in crosses with *M. crispa* to produce Verticillium wilt-resistant seedlings, but they proved inferior to those from crosses between *M. spicata*, Scotch, and *M. crispa*. Of perhaps some significance were the similar indices of rust infection in 1951 on the five clones of *Mentha spicata* that had not rusted in 1950. Whereas those that were attacked both in 1950 and 1951 were heavily rusted both seasons, others that rusted only in 1951 were only lightly infected. This would support the conclusion that these plants were infected only with the race that infected *M. piperita* in 1951 and that these clones are genetically similar in their resistance to rust.

In no season prior to 1951 has any hybrid seedling coming from crosses between *Mentha piperita* and *M. crispa* rusted at Mentha or at East Lansing. Accessions 45 and 54 of this parentage, however, were lightly rusted in the nursery in 1951. Two seedlings, accessions 57 and 59, from crosses between a fertile, polyploid clone of *Mentha piperita* and wilt-resistant seedling No. 39-08 (Accession No. 50) were also rusted very lightly. Seedling No. 39-08, however, has not rusted in 13 years of testing at Mentha and East Lansing.

These reactions to rust indicate that the races of *Puccinia menthae* in the mint nursery at East Lansing in 1950 and 1951 do not conform in their host relationships with races 1 and 2 reported by Baxter as infecting *Mentha spicata* and *M. piperita*, respectively. Neither does it seem likely that the greatly extended host range of rust in 1951 was the result of the abrupt appearance of numerous new races of *Puccinia menthae*. It is possible that the races on the nursery plants differed from those with which Baxter worked, as seems likely from the host relationships. The consistent rust reactions of the mints in the nursery at Mentha for many years, including seasons when the disease was severe in commercial plantings on the Todd Plantation, are evidence that there was stability in the race or races involved. There was no observed extension of the limited host range from 1939 to 1951, inclusive, at that location. At East Lansing there were similar consistent reactions to rust in 1949 and 1950, reactions which paralleled those at Mentha. The greatly extended host range of rust at East Lansing in 1951 was apparently consequent to the appearance of one or more new races of *Puccinia menthae*. Peppermint did not rust at Mentha and

in many other sections of Michigan in 1951 despite very favorable environmental conditions for the development of the disease, as shown by the heavily rusted condition of spearmint at Mentha and in other mint areas.

CONTROL

GENETICAL

The most practical and the most effective method of controlling rust will result from the development of resistant varieties. This has been demonstrated in the production of numerous species hybrids that are resistant to the races that have so far appeared on mints in Michigan. Resistance in these hybrids has been inherited from *Mentha crispa* which has been used as the pollen parent in the breeding of wilt and rust-resistant varieties of peppermint and spearmint. Resistance to rust has not been difficult to incorporate in the hybrids, but some other essential characteristics have been. High yields of good quality oil, rapid propagation, earliness and good growth habits are factors of great importance, and it has been difficult to combine all of these with disease resistance. Satisfactory oil quality has been especially elusive in the peppermint hybrids, but this factor has been easier to incorporate in the spearmints. It is anticipated, however, that resistance to both wilt and rust can be combined with other required characters to produce acceptable peppermint and spearmint hybrids.

Three-fourths of the 3,500 hybrids between *Mentha spicata* Scotch and American, and *M. crispa* tested at Mentha in 1948 for wilt and rust resistance were resistant to rust. A number of the most promising seedlings were selected, propagated and tested in 1949, 1950 and 1951. Of these only one has survived the critical testing to which they have been subjected. This seedling has not developed rust at Mentha and at East Lansing, although growing near other mints that have been severely attacked. This indicates that this hybrid is resistant to the races that were present at Mentha and at East Lansing in 1950 and 1951, including the rust that attacked peppermint in 1951.

None of the several thousand seedlings arising from crosses between *Mentha piperita* and *M. crispa* has developed rust in the disease resistance tests at Mentha. This record extends from 1939 to 1951, but during that time no rust appeared on *Mentha piperita*. Nursery accessions Nos. 45 and 54 developed only a trace of rust at East Lansing in 1951 when *Mentha piperita* was heavily rusted. This indicates that these seedlings are highly resistant to the new race that attacks pepper-

mint. All other seedlings of this parentage grown in the nursery in 1951 were rust-free. This demonstrates that resistance is attainable in these hybrids though its stability may ultimately be upset by the appearance of new races of the rust fungus.

More recent results with a new source of rust resistance may yield better hybrids than those obtained by using *Mentha crispa* as the resistant parent. Some of the undesirable factors present in most of the species hybrids may be avoided by using this new source of resistant genes. This anticipation is of paramount importance in the breeding work and could lead to an earlier solution of the problem of developing satisfactory disease-resistant hybrids of both peppermint and spearmint types.

CONTROL WITH FUNGICIDES

That rust can be controlled with fungicides has been demonstrated in the results of field experiments at Mentha in 1948 and 1950. In 1950 rust was so severe that the undusted control plants were defoliated. Environmental conditions were so unfavorable for rust in 1949 that benefits from dusting were not demonstrable.

MATERIALS AND METHODS

All experiments on the control of rust with fungicides were conducted on the Todd Plantation with the Scotch variety of spearmint. Dusting was chosen as the method of applying fungicides since most mint growers dust to control the mint flea beetle. Only row mint was used in these experiments because of practical difficulties in using land dusters in meadow plantings. A Niagara Cropmaster duster, equipped for the dusting of four rows with two nozzles to each row, was modified by removing four of the nozzles so that two rows could be dusted more thoroughly. The discharge velocity of the dust is insufficient to assure good coverage of the plants when this duster is used with eight nozzles. The nozzles could not be adjusted, however, to discharge the dust against the lower surfaces of the leaves where all rust infection occurs. The dust columns from a nozzle on each side of the row were directed toward the centers of the plants so that in converging they produced a swirling cloud of dust that enveloped all plants in the row. By dusting only in the evening after winds had subsided more effective coverage of the plants was obtained.

The first application was not made until rust was apparent on the lower leaves. This was usually about the middle of July, and the

number of applications was determined by the time of harvest or other disposition of the planting. The rates of application of the dusts used varied from 40 to 60 pounds per acre. With the same nozzle aperture the quantity of dust discharged was greater under low atmospheric humidity than when the moisture content was high.

The comparative effectiveness of the dusts in rust control was determined by visual inspections of an equal number of plants in each of the plots. These inspections were made before each application, and a final rating was given at the time of harvest.

MATERIALS AND RESULTS IN 1948

The following fungicides were used in the 1948 experiments:

1. Dithane Z-78, 6 percent;
2. Dithane Z-78, 6 percent plus 10 percent dusting sulfur;
3. Fermate, 10 percent, and
4. Yellow copper oxide, 6 percent plus 10 percent dusting sulfur.

When these experiments were begun it was not known that carbon disulfide appears in the oil from plants dusted with organic sulfur compounds like Fermate and Dithane. It was known that sulfur was used many years ago for the control of rust in spearmint and that the oil from dusted plants had an undesirable flavor which disappeared with aging of the oil and the attendant oxidation of the sulfur compounds. Carbon disulfide was not identified with these foreign flavors. Following the outbreak of rust in Oregon and Washington in 1949 and 1950 and tests of Dithane for its control, it was found that carbon disulfide is a toxic residue of steam distillation of the plants dusted with this material. The use of this, and other carbamates, is now precluded unless a suitable method of removing this residue from the oil is found. In these early experiments on rust control the 10 percent sulfur added both to Fermate and Dithane was intended to increase their fungicidal effect without causing a pronounced off flavor in the oil that accompanied the use of 100 percent sulfur dust.

The experimental plots were dusted five times in 1948, July 8, 15, 21, 29 and August 13. The 15-day interval between the fourth and fifth applications was a consequence of weather unfavorable for rust infection. The final application on August 13 could have been omitted since the plants were mature and the harvest time was less than 2 weeks away.

Rust developed to only a moderate extent on the undusted plants, and defoliation was insufficient to influence yields significantly. Rust lesions were numerous on the lower leaves of the control plants and there was some defoliation from the combined effect of rust and leaf spot. The most effective protection against rust was evident in the plots dusted with Fermate. It was difficult to find rust lesions on the lower leaves and it was apparent that few infections had occurred subsequent to the first application. Control was also satisfactory with the Cuprocide-sulfur dust. There was more rust on the plants dusted with the Dithane-sulfur combination and the Dithane without sulfur was the least effective of all.

Plots of 4 square rods each were harvested from the dusted plots. There were no significant differences in yields of oil. Samples of the oils were submitted to the Wm. Wrigley Jr. Company for evaluation. The oil from the copper oxide-sulfur plots was judged abnormal in flavor. The others were pronounced satisfactory in a comparison with the sample from the undusted plots. No assays were made to detect the presence of undesirable residues in the oils.

MATERIALS AND RESULTS IN 1950

The field selected for dusting in 1950 was planted late and was the last one harvested on the Todd Plantation that season. Rust was abundant on the lower leaves at the time of the first application of the dusts. Conditions were favorable for rust infection, but the early-harvested fields were not damaged. Spread and development of rust was rapid in August, and the latest-harvested fields were severely rusted and partially defoliated. Oil yields were reduced as much as 70 percent.

The experimental plots were not harvested at the normal time and dusting was continued into September to determine whether rust could be controlled under the most favorable conditions for its development. Rust increased rapidly in late August and through September and the undusted plots were completely defoliated at the end of September (Fig. 4 E).

The following fungicides were used in 1950:

1. Dithane Z-78, 6 percent;
2. Fermate, 10 percent;
3. Tribasic Copper Sulfate 14 pounds plus 4 pounds neutral zinc (NuZ) to 100 pounds of dust,
4. Acti-dione, 2 percent.

The Fermate dust was included as a standard of comparison since it had controlled rust in the 1948 experiments. Dithane without sulfur was included because it had been used for rust control elsewhere. The Acti-dione dust was prepared from the dried carbon adsorbate which assayed 2 percent active material. Preliminary tests with this dust had shown it to be very effective in the control of rust on snapdragons.

Six applications of the dusts were made, August 3, 11, 18, 25, September 7 and 15. The last two applications were put on after the close of the distillation season on the Todd Plantation. Rust increased with great rapidity in September and marked differences in the effects of the dusts were readily apparent. An improved arrangement of the nozzles resulted in a more nearly complete coverage of the lower surfaces of the leaves in the fifth and sixth applications. This, together with increased amounts of dust applied, prevented further spread of rust in all of the dusted plots except those treated with Dithane. The general appearance of the plants in those plots showed that this fungicide was not effective in preventing rust infection.

The plots dusted with Fermate remained green and practically rust-free until the plants were harvested in October (Fig. 4, E). The protective effect of this fungicide extended for three weeks subsequent to the time of the final application and was also apparent in half of the adjacent row of the undusted control plot which was partially protected by the dust drifting from the dusted rows. In no other plot was a protective effect noted on the undusted plants adjacent to a dusted row.

The undusted plants in the control plots were completely defoliated by rust (Fig. 4, B), and those dusted with Dithane were so severely affected that most of the leaves were cast (Fig. 4, B). The plants dusted with Tribasic Copper Sulfate-zinc and with Acti-dione were in comparable condition (Fig. 4, D). There was considerable defoliation on the lower half of the plants in these plots. Most of this defoliation however, was a result of infections that occurred prior to the fifth and sixth applications of dust. If the earlier applications had accomplished as nearly complete coverage of the lower surfaces of the leaves as the fifth and sixth ones, it is likely that this rust damage would have been reduced. Since environmental conditions were optimum for infection in August and September, the degree of rust control obtained with these fungicides is an indication that they would be effective in the control of rust under seasonal conditions that normally prevail in Michigan. It is likely, moreover, that they would afford adequate pro-

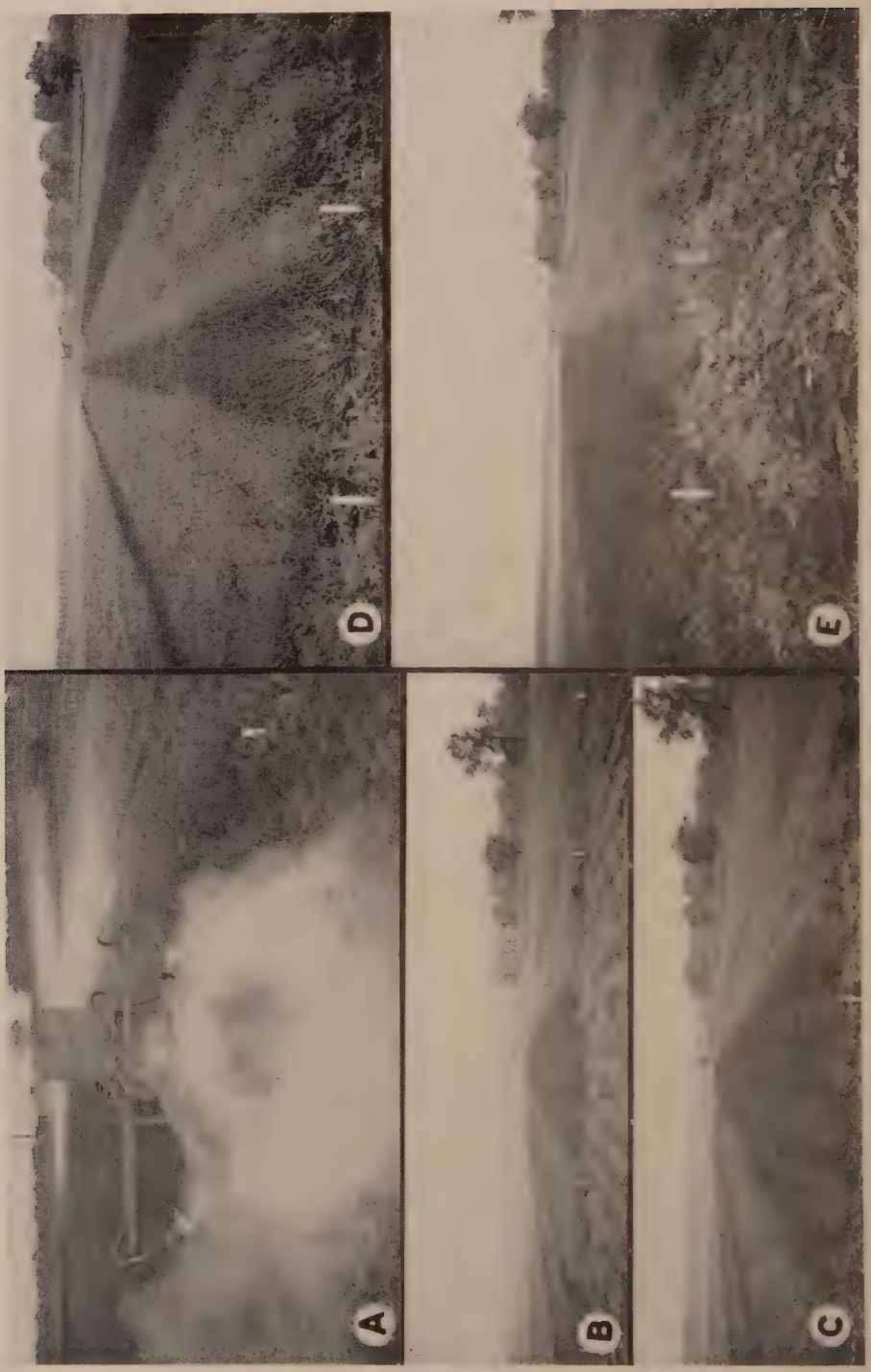

Fig. 4. (See page 453.)

tection against rust in commercial plantings where harvest is usually completed by late August. In these experiments they effectively checked the spread of rust in September when the mint leaves were well covered with dust.

Comparable areas were harvested in early October from the plots dusted with Fermate, Tribasic Copper Sulfate-zinc and with Acti-dione. Significantly higher oil yields were obtained from the Fermate plots. Yields were approximately equal from the other two. Assays of the oils from the Fermate plots revealed the presence of 10 ppm. of carbon disulfide. This low residue was undoubtedly related to the long interval between the final application of the dust and distillation; up to 500 ppm. of this compound have been found in the oils from plants dusted with Fermate and harvested before rains removed any of the dust.

DISCUSSION

The initial development of rust in commercial plantings of peppermint in Michigan in 1951 introduced a new and serious control problem for the Michigan mint industry. The production of peppermint oil has markedly declined in Michigan during the past decade. This decline is largely attributable to Verticillium wilt and to depleted soil fertility. Yields are now barely high enough in some sections to defray the cost of production. Leaf diseases on both peppermint and spearmint have been of minor importance with the exception of years when the late-harvested fields of spearmint have been damaged by rust. Should peppermint rust become destructive in the midwest a control program would add considerably to the cost of production. That the

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Fig. 4. A—Dusting with the two-row duster used for applying fungicides in rust control experiments on Todd Plantation 1948, 1950. The air was quiet and the dust cloud completely enveloped all plants in the row.

B—General view of the rust control experimental plots at Mentha, 1950.

C—Six rows of undusted Scotch spearmint plants in the 1950 rust control plots.

D—Four rows of plants dusted with Tribasic Copper Sulfate-zinc (right) and 4 rows dusted with 2-percent Acti-dione (left). The center row of dead plants had not been dusted.

E—Four rows (right) dusted with 10-percent Fermate. Almost complete control of rust was achieved with six applications. All top growth has been killed by rust on the adjacent, six undusted rows. Fermate and other sulfur fungicides, can not be used on mint because they break down in distillation and form undesirable residues which appear in the oil.

disease can be destructive is shown by its extensive development in Oregon and western Washington in 1949 and 1950. Fortunately, however, climatic conditions are less favorable for rust in the midwest. The disease is, however, likely to be more serious in peppermint because it normally is harvested later than spearmint.

Rust in spearmint will probably be controlled by the development of resistant varieties. Already tests are being made with hybrids between Scotch spearmint and *Mentha crispa*. These hybrids are resistant to the races of rust that have appeared so far in Michigan. They are high-yielding plants, and if the oil quality proves satisfactory they should remove the hazard of losses from rust in Michigan.

The prospect for rust control in peppermint by resistance is less likely to be resolved as quickly as in spearmint because the factor of oil quality is more difficult to capture than in the spearmint hybrids. Among the several thousand hybrid peppermint seedlings grown on the Todd Plantation since 1939, none has produced oil of completely satisfactory quality. Most of these hybrids have been resistant to rust. Only two of them developed a very light infection in 1951 in comparison with severe damage to commercial peppermint. They are apparently either immune from, or highly resistant to, the new race of rust that attacked peppermint in 1951. There is no assurance, however, that they will not be attacked at some future time by new races of the rust fungus. This method of control, however, offers the most satisfactory solution of the rust problem and it is likely to be successfully utilized.

The results of the 1948 and 1950 tests with fungicidal dusts show that rust can be controlled, at least in row mint, by this method. Though the use of Fermate, the most efficient fungicide tested so far, is precluded there are others that undoubtedly will effectively control rust in Michigan. Tribasic Copper Sulfate combined with zinc oxysulfate and applied in dust form should prevent rust infections if the dusting is thorough and timely.

The most serious development of rust occurs in meadow plantings and the use of land dusters has not been tested in such plantings. Plane dusting is possible and if done by experienced pilots should provide good protection. Experience gained in plane dusting of onions for control of downy mildew has revealed the necessity of making two flights in opposite directions to obtain complete coverage of the plants. With only a single flight the plants are coated with dust only on one side because of the velocity imparted to the dust particles by the flying

plane. Applying half of the dust from one direction and the other half from the reverse direction will result in a much more effective coverage. This method will require more dust than will applications to row mint by land dusters.

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POTENTIAL MICHIGAN PUBLIC SCHOOL ENROLLMENTS

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A RAPIDLY RISING number of births necessitates an annual review of potential school enrollments and an appraisal of needs for additional teachers and school buildings. In a number of localities, especially in suburban fringe areas, the number of children of pre-school age now nearly equals the present enrollment in all twelve grades and kindergarten combined. The anticipated rapid growth of the school population, owing to large numbers of wartime and post-war babies, is nationwide. The situation is somewhat more acute, however, in Michigan than in most states because of the unusually rapid growth of its population by in-migration from other states and by the relatively high fertility of both its urban and rural-nonfarm residents.[2]

In the United States, nearly 8 million more babies were born during the 1940's than during the 1930's. Furthermore, preliminary figures indicate that there was a record number of 3,833,000 births in 1951, exceeding the previous high of 3,818,000 in 1947. This foretells the need of many more teachers and classrooms in the future. School men, school board members, and citizens' committees are trying to arouse their constituents to the need for preparedness for the oncoming hordes of school children.

A knowledge of births and in-migration during the past decade or more makes possible a rather close approximation of the potential increase in school population in Michigan, year by year and grade by grade, for a period of years. During the 10-year period of 1942-51 inclusive, births in Michigan totaled 1,411,324, or nearly half a million more than during the 10-year period preceding 1942. In 1947, there were born in Michigan a total of 158,781 babies, and it was apparent

[1]Deputy Superintendent, Michigan Department of Public Instruction.

[2]J. Allan Beegle, "Differential Birth Rates in Michigan," Mich. Agr. Exp. Sta. Spec. Bul. 346 (Feb. 1948), p. 25.

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then that when these youngsters entered kindergarten about 5 years later, in the fall of 1952, the state would have the beginning of a 13-year bulge in its school enrollment. It is now known that the all-time record enrollment of about 146,000 children in the kindergartens next fall will be just the first of a series of such huge groups of beginners. This is because the baby boom which started in 1947 has continued to 1952. The babies born in 1951 totaled 171,568 (provisional), or 11,653 more than those born in 1950, the previous peak year of births. Most of the babies born in 1951 will be entering kindergarten in the fall of 1956. Some 13 years later, in 1969, they will be finishing the twelfth grade.

It appears that last year's enrollment of 1,067,535 in the public schools of Michigan may quite likely increase to about 1,388,000 within the next 5 years. Therefore, Michigan must build 10,700 additional classrooms for 321,000 additional children before 1957, not to mention replacement of outworn school plants. Furthermore, school enrollments will continue to mushroom for many years after 1955-56, even with a drop in births and in the birth rate (number of births per 1,000 population).

The 321,000 additional public school enrollees in Michigan within 5 years, if this forecast proves correct, will require 10,700 additional classrooms, estimating 30 pupils per class. At an average cost of $25,000 per classroom, this would require an outlay of $267,500,000. Need for expanded school buildings will be *greatest in the rural areas adjacent to metropolitan centers*—in the suburban fringe areas. In numerous school districts the children under 4 years of age total from one-half to four-fifths the present enrollment in all 12 grades plus kindergarten, excluding non-residents. This is the situation in such places as Farmington, Royal Oak, Berkley, Hazel Park, Madison, East Detroit, Roseville, Lakeview (Macomb County), South Lake, Livonia Township, and Romulus Township.

The increase in school population will be very uneven within the state and even within counties unless it is counteracted by extensive school district reorganization. These inequalities present a challenge to the Area Study Committees already organized in 24 counties as a result of legislation passed in 1949. Such groups may appraise their century-old school district structure and proceed democratically in the equalization of growing inequalities, by means of the creation of community school districts and community schools.

Increasingly larger total school enrollments have been experienced annually since 1944. Furthermore, these can be expected to continue to rise annually, and by substantial amounts, for another decade at least. Previous to 1948 the total enrollment in the public schools of Michigan had never totaled as many as one million, including both elementary and secondary schools. It is very probable that within 4 years the enrollment in the elementary grades (kindergarten - 8) of the public schools alone will exceed one million. In addition, there are likely to be over a quarter-million youth in the high schools (grades 9-12). Part of the growth is due to in-migration from other states and countries. Of the total migration of about 361,000 persons from other states between the census years of 1940 and 1950,[3] perhaps 90,000 were youngsters of school age, 5 to 19 years.

A METHOD OF FORECASTING FUTURE PUBLIC SCHOOL ENROLLMENTS

A number of different methods make it possible to forecast future public school enrollments. The satisfactory use of several methods awaits the publication of the 1950 census data pertaining to age distribution, school attendance, and life tables.

One method for estimating future school enrollments may be called the "attrition rate." It is a measure of the number of survivors of children in a given grade, plus additions, to those in the preceding grade the previous year. A study of the enrollment in a given grade in comparison with that in the preceding grade the previous year and the constancy, variability, and trend of the ratio over a period of years may serve as a basis for projecting future school membership.

Table 1 shows the year-end enrollment in the public schools of Michigan, by grades, for 1949 and 1950, and the percentage that the enrollment in 1950 was of the enrollment in the preceding grade for 1949. The enrollment in kindergarten in 1949-50 was 98,973, or 87.13 percent of the 113,586 registered births that occurred in 1944, 5 years previously. Not all youngsters enter kindergarten at the age of 5 and, therefore, less than 100 percent of those born in 1944 were in kindergarten in 1950. The proportion of 5-year-old children attending school has been rising steadily in Michigan. Parenthetically, the U. S. Census for 1940 showed that the percentage of 5-year-old children in Michigan attending school, namely 51 percent, was higher than in any other state.

[3] John F. Thaden, "Contribution of Natural Increase and of Migration to Michigan's Population Changes". Michigan Agricultural Experiment Station Quarterly Bulletin 34 (August 1951): 9-16.

The present enrollment in kindergarten in Michigan, 87 percent of those who were born 5 years previously, is a higher percentage than in any previous year, at least as far back as 1932.

TABLE 1—Year-end enrollment in the public schools of Michigan, by grades, 1949 and 1950

Grade	1949	1950	Percent that enrollment in 1950 is of the enrollment in the *preceding grade* in 1949
Kindergarten	106,630	98,973	*
First	111,830	111,999	105.04
Second	91,110	102,370	91.54
Third	84,190	89,618	98.36
Fourth	80,510	83,318	98.96
Fifth	78,960	79,666	98.95
Sixth	74,140	79,012	100.07
Seventh	72,120	74,793	100.08
Eighth	67,840	70,547	97.82
Ninth	64,020	68,701	101.27
Tenth	56,590	59,466	92.89
Eleventh	49,000	50,644	89.49
Twelfth	45,090	46,096	94.07
Other	41,970	28,363	.....
Total	1,024,000	1,043,566	.....

*The enrollment in kindergarten in 1950 (98,973) was 87.13 percent of the total births (113,586) in 1944, or 5 years previously.

Some children do not enroll in kindergarten but enroll in the first grade when they enter school at the age of 6. This largely explains the enrollment of 111,999 in grade 1 in 1950, which is 105 percent of the enrollment in kindergarten the previous year.

It will be noted from Table 1 that only about 9 in 10 of those in the first grade are to be found in the second grade the next year. This relatively low proportion is explained by the fact that there is a tendency for some families to send their children to the kindergarten and the first grade of the public school and then send them to a parochial school. Very few parochial schools cater to youngsters of kindergarten age.

About 98 percent of youngsters pass from the second grade to the third grade. A like proportion also pass from the third grade to the fourth grade and from the fourth grade to the fifth grade. It will be noted that the number enrolled in the sixth grade exceeds that in the fifth grade the preceding year. This is possible when a number of youth transfer from private and parochial schools to public schools

as some do. The public senior high school and junior high school also receive many youngsters who attended parochial schools in the lower elementary grades. The relatively high enrollment in a given grade is also possible as a result of a considerable increase in population through in-migration. No doubt both of these factors contributed to some percentages exceeding 100 as shown in Table 1. The same explanation can be given for the enrollment in the seventh grade outnumbering that in the sixth grade and the enrollment in the ninth grade exceeding that in the eighth grade, the preceding year.

The relative completeness and accuracy of annual school census enumerations in Michigan facilitate accuracy of school population forecasts. Locally, the enumeration of pre-school children at the time of the regular school census in May, as provided in laws passed by the Michigan (one of five states with this provision) legislature in 1944, enables one to foresee more clearly future school enrollments and building needs.

BASIC ASSUMPTIONS

In attempting to forecast future public school enrollments in Michigan by the "attrition rate," one has to make assumptions regarding continuation of past trends. One faces such questions as, "Will the ratio of enrollment in kindergarten to births 5 years previous continue to rise?" "Will the ratio of future enrollment in grade 1 to that in kindergarten the previous year continue to drop?" "Will the ratio of future enrollment in grade 2 to that in grade 1 the previous year continue to increase?" and "Will the rise or fall, if any, be greater during the next few years than in recent years?"

To illustrate, in 1932-33 the enrollment in kindergarten was 62.2 percent of those born in 1928, or 5 years previously. The percentage of enrollment in kindergarten to those born 5 years previously has risen steadily since 1933 and is now 90.3. This is an average annual rise of 1.5 percent. Never has the percentage been so high as it is now. The enrollment in kindergarten from 1943 to 1949 averaged 85.3 percent of those born 5 years previously; the average for the past 3 years was 87.5 percent. The steady rise has been due apparently to a constantly increasing proportion of youngsters starting to school before age 6. Michigan school laws are favorable to 5-year-old children attending school. Opportunities for women to earn money should encourage families to send their 5-year-old children to school. The rising cost of living in relation to income of husbands and, therefore, the increasing

need for wives to supplement the income of their husbands would also encourage the sending of children to school as soon as possible. Continued school district reorganization and the increased number of youngsters living in graded school districts having kindergartens would stimulate early school attendance of rural children. On the basis of these possibilities and others, it is here assumed that the enrollment in kindergarten will continue to be a slowly rising proportion of those born 5 years previously, namely 1.0 percent a year for each of the next 3 years and constant the two following years. The result is shown in Table 2.

TABLE 2—Estimated ratio of enrollment in given grade to that in preceding grade previous year, 1951-56

Grade	Actual			Estimated				
	1948 to 1949	1949 to 1950	1950 to 1951	1951 to 1952	1952 to 1953	1953 to 1954	1954 to 1955	1955 to 1956
Birth to kindergarten...	85.00	87.13	90.28	91.3	92.3	93.3	93.3	93.3
Kindergarten to Grade 1.....	106.42	105.04	104.59	103.6	102.6	101.6	101.6	101.6
Grade 1 to 2.....	92.01	91.54	94.48	94.9	95.2	95.4	95.5	95.5
Grade 2 to 3.....	98.01	98.36	98.27	98.4	98.5	98.6	98.6	98.6
Grade 3 to 4.....	97.80	98.96	99.48	99.5	99.5	99.5	99.5	99.5
Grade 4 to 5.....	97.52	98.95	99.48	99.5	99.5	99.5	99.5	99.5
Grade 5 to 6.....	98.20	100.07	100.00	100.0	100.0	100.0	100.0	100.0
Grade 6 to 7.....	99.32	100.08	100.61	100.5	100.4	100.3	100.3	100.3
Grade 7 to 8.....	95.51	97.82	97.68	98.0	98.0	98.0	98.0	98.0
Grade 8 to 9.....	97.50	101.27	99.17	98.5	98.6	98.7	98.8	98.9
Grade 9 to 10....	89.01	92.89	89.06	88.6	88.7	88.8	88.9	89.0
Grade 10 to 11...	86.01	89.40	84.99	84.0	84.3	84.6	84.9	85.2
Grade 11 to 12...	89.00	94.07	88.66	87.7	88.1	88.5	88.9	89.3

As the ratio of enrollment in kindergarten to the number of births 5 years previously rises, there is a strong tendency for the ratio of enrollment in grade 1 to enrollment in kindergarten in the previous year to drop. Since it is here assumed that the ratio of kindergarten enrollment to births 5 years previously will rise 1.0 percent a year, it is reasonable to assume that the ratio of enrollment in grade 1 to kindergarten the previous year will drop proportionately.

The enrollment in grade 2 is 94.5 percent of enrollment in grade 1 the previous year. This is a larger figure than at any time during the past two decades. The figure rose fairly steadily from 91.2 from 1945 to 94.5, an average increase of 0.6 a year. The increase from 91.5 of a

year ago to 94.5 is unusual, and future increases can be expected to be much less. It is here assumed that the ratio of enrollment in grade 2 to that in grade 1 the previous year will rise in successive years as follows: 0.4, 0.3, 0.2, 0.1, 0.0.

It is assumed that the ratio of enrollment in grade 3 to that in grade 2 the preceding year will rise 0.1 percent each year for three years and remain constant thereafter. The figure of 98.3 last year was exceeded six times during the past two decades.

It will not be necessary to indicate all of the facts and factors that were taken into consideration in arriving at the estimated percentage that enrollment in grade 4 to that in grade 3 the previous year is expected to be each year for the next year, nor for the grades following. The results of such considerations are shown in Table 2. It is assumed that the ratio of enrollment in grade 4 to that in grade 3 the previous year, and from grade 4 to 5, grade 5 to 6, and grade 7 to 8, will remain essentially unchanged for the next five years. Obviously, the ratio of enrollment in a given grade to that in the preceding grade the previous year will not necessarily be constant, as assumed: it may be as irregular during the next 5 years as it was during the past 5 years. However, the nature and extent of probable future irregularities are not readily apparent. For the compulsory school attendance years, 6 to 16, the irregularities are not likely to be greater in the future than they have been in the past.

The present unsettled Korean affair complicates the forecasting of high-school enrollments, especially in the twelfth grade. The cessation of the present military conflict will cause the high-school enrollments to be larger than is forecast in view of present conditions. A possible growth of the community college will have a similar effect. Economic conditions within the state will be a factor that affects in-migration of families and consequently school enrollments. The primary purpose of this appraisal of potential public school enrollments is to arrive at some approximation of total public elementary school enrollment and total public high-school enrollment rather than the possible enrollment in each grade. However, it is possible, by the method of forecasting used here, to secure approximate enrollment in each grade at the same time.

In 1950-51, the number of students classified as "others" enrolled in the public schools of Michigan totaled 26,053. This is a considerable reduction from the 5-year average of 37,700 preceding 1951. It reflects the influence of the Korean war. Most of the students classed as "other"

are older students who are attending school part-time and are enrolled in continuation courses. Their future number is most difficult to foresee and has been assumed to be constant at 30,000 after 1952-53.

ESTIMATED FUTURE PUBLIC SCHOOL ENROLLMENT

The public schools of Michigan had an enrollment in grade 2 in 1950-51 of 105,813 (Table 3). This was a larger enrollment than in any other grade that year. These pupils are the war babies of 1943 when a larger number were born than in any previous year in the history of Michigan. However, the figure of 125,441 births in 1943 has been exceeded six times since—every year from 1946 to 1951. The high forecasted enrollment in kindergarten in 1951-52 and subsequent years reflects the high post-war births.

TABLE 3—Forecast of future enrollment in the public schools of Michigan

Registered births.	138,572 (1946)	158,781 (1947)	152,610 (1948)	155,226 (1949)	159,915 (1950)	171,568* (1951)
Grade.....	1950-51†	1951-52	1952-53	1953-54	1954-55	1955-56
Kindergarten.....	100,716	126,520	146,560	142,390	144,830	149,200
1.....	103,519	104,340	129,810	148,900	144,660	147,140
2.....	105,813	98,240	99,330	123,830	142,200	138,150
3.....	100,598	104,120	97,770	97,940	122,100	140,210
4.....	89,149	100,100	103,600	96,280	97,450	121,490
5.....	82,884	88,700	99,600	103,080	95,800	96,970
6.....	79,664	82,880	88,700	99,600	103,080	95,800
7.....	79,496	80,060	83,220	88,970	99,890	103,390
8.....	73,059	77,910	78,460	81,550	87,190	97,890
K–8.....	814,898	862,870	927,050	982,540	1,037,200	1,090,240
9.....	69,962	71,960	76,820	77,440	80,570	86,230
10.....	61,183	61,990	63,830	68,210	68,840	71,710
11.....	50,539	51,390	52,250	54,000	57,910	58,660
12.....	44,900	44,320	45,280	46,250	48,000	51,710
9–12.....	226,584	229,660	238,180	245,900	255,320	268,310
Other.....	26,053	25,000	25,000	30,000	30,000	30,000
TOTAL...	1,067,535	1,117,530	1,190,230	1,258,440	1,322,520	1,388,550

*Figures are provisional, as of May 1, 1952.
†Figures are provisional. Final figures may be available in August 1952.

The enrollment in kindergarten can be expected to be very large for a number of years—larger than that in any of the elementary grades in 1951-52, 1952-53, 1954-55, and 1955-56. In 1953-54 it will probably

be second only to the enrollment in the first grade. These beginners will, of course, later contribute their large numbers to the enrollment in the various elementary grades and in high school.

As far as the next 5 years are concerned the peak enrollment in kindergarten will probably be attained in 1955-56; in grade 1 in 1953-54; in grade 2 in 1954-55; in grade 3 in 1955-56; in grade 4 in 1955-56; in grade 5 in 1953-54; in grade 6 in 1954-55; and in grades 7 and 8 in 1955-56. The enrollments in grades 9, 10, 11, and 12 can be expected to increase yearly, except possibly for a slight decrease this year over last year in grade 12.

The enrollment in each grade can be expected to be substantially larger in 1955-56 than in 1950-51. According to the forecast indicated in Table 3, the enrollment will be 48 percent larger in kindergarten, 42 percent larger in the first grade, 30 percent higher in the second grade, 39 percent larger in the third grade, 36 percent larger in the fourth grade, 17 percent larger in the fifth grade, 20 percent larger in the sixth grade, 30 percent larger in the seventh grade, and 34 percent larger in the eighth grade. In all elementary grades and kindergarten combined the enrollment will be about 30 percent larger, an average increased enrollment of nearly 6 percent per year. In most suburban areas the increase will be much greater. The enrollment in grades 9 through 12 will be about 18 percent higher in 1955-56 than last year.

There are more imponderables in forecasting high school enrollments than elementary school enrollments, especially beyond the compulsory school attendance years of 6 to 16. Just prior to the Korean war there were probably over 40,000 youth of high school age in Michigan who were not in school nor employed. It should be possible to get into school more youngsters of teen age in Michigan. According to the census of 1940, Michigan's rank among the states in school attendance of youngsters of high school age was as follows: 11th for 14-year old children, 14th for the 15-year old children, 17th for the 16-year old children, and 21st for the 17-year old children. The percentages of these ages attending school were 96.1, 92.4, 80.9 and 65.1, respectively. Had as large a percentage of youngsters of these ages in Michigan attended school as in Utah and California in 1940, then about 346,000 would have attended school instead of only 318,000, or some 28,000 more.

Many factors can influence the holding power of students in the upper grades, when they have out-lived the compulsory school attendance years. In rural counties, school district reorganization, with an

enriched curriculum, seems to strengthen the interest of many youth in their studies. According to the U. S. Census of 1940, in 14 counties of Michigan some 70 percent or more of the farm children 16 and 17 years of age were attending school. Most of these counties at that time had already restructured their hundred-year-old school districts considerably. This was more particularly true in the counties of Manistee, Crawford, Wexford, Oscoda, and Benzie.

In some respects, communities with extensive school district reorganization will be best able to plan constructively and to build adequately, if their electorates can foresee a future with a doubled, tripled, or quadrupled school population. Oakland County is possibly the outstanding county which has made annual progress since 1922 in this respect. About 90 percent of the 396,000 people of this county now live in 17 community or partial-community school districts, within which the shock of rapidly increasing school populations can be readily absorbed. About a dozen counties have made considerable progress in school district reorganization since 1944, following the publication of the findings and recommendations of the Michigan Public Education Commission. Area Study Committees, now active in 24 counties, through their meetings, reports, and recommendations, can stimulate and hasten the organization of community school districts that can effectively meet problems incurred by rapidly increasing school population.

DIAGNOSTIC TECHNIQUES USED IN SOIL FERTILITY STUDIES

By K. LAWTON, L. S. ROBERTSON, R. L. COOK, and P. J. ROOD
DEPARTMENT OF SOIL SCIENCE

IN RECENT YEARS a number of diagnostic techniques have been used with soils and crops to evaluate soil fertility conditions. These methods include rapid soil tests, plant tissue tests, plant ash analyses, and appraisal of nutrient deficiency symptoms. Each individual technique has limitations in its use and application.

Rapid soil tests are abbreviated chemical analyses for the more soluble nutrients in soils. On field soils these tests are usually made before planting time to help the farmer determine whether additional lime or fertilizer is needed for maximum crop production. However, physical conditions of the soil, such as poor aeration, lack of moisture, or low soil temperatures may greatly influence the plant's ability to use the nutrients present in the soil.

Plant tissue tests are chemical analyses of the plant sap or sap extracts and represent very largely the nutrients not already combined in plant tissue at the time the test is made. Several tissue analyses are needed over the growing season to ascertain adequately the changing nutrient needs of a crop.

Ash analyses are a measure of the total content of mineral elements in plant tissue. Since crops tend to maintain their quality and composition at the expense of yields, tests of the ash are not always a reliable measure of the actual nutrient requirement of plants.

Deficiency symptoms or hunger signs are expressions of physiological disturbance or unbalance within the plant when one or more nutrients are low. These hunger signs represent advanced stages of crop needs, and after they are observed it is often too late in the growing season to make supplemental additions of plant food.

It is not uncommon to utilize several diagnostic techniques in field crop studies. However, few widespread surveys of soil fertility condi-

ARTICLE 34-54

tions make use of all available methods. In this study an attempt was made to correlate all of these techniques for evaluating soil fertility conditions at 66 locations in 35 Michigan counties where simple fertilizer trials were conducted on legume and legume-grass hays. Phosphate and potash fertilizers were applied as top dressings at the rate of 750 pounds per acre of 0-20-0, 0-0-20, and 0-20-20. Two years' yield data were supplemented with data from soil and plant tissue tests, and from ash analyses made on the mature plants.

YIELD RESPONSE FROM FERTILIZER

Significant increases in first-cutting hay yields from the use of superphosphate fertilizer were obtained on 58 soils. Where only potash was applied, significant yield increases were obtained on 41 fields, while virtually all fields which received both phosphate and potash produced substantially more hay than did those not fertilized. The average yields for all trials are shown in Table 1. The total increase due to phosphate was exactly 1 ton per acre during both years. It is interesting to note that the residual fertilization the second year produced yields that were almost as great as those of the first year of application.

The increase in yield due to the application of potassium was much smaller than that received as a result of phosphate fertilization, the total for the two years being 0.19 ton. It is interesting, though, that the mixed fertilizer containing both phosphate and potash caused yield increases that were greater than the sum of the yield increases from each nutrient applied singly.

TABLE 1—Average yield and phosphorus, potassium, and nitrogen content of first-cutting hay as affected by fertilizer treatments over a 2-year period

Treatment	Average yield, tons per acre		Nutrient content, in percent (1946 only)		
	1946	1947	P	K	N
Check	1.75	1.76	0.19	1.02	2.36
Phosphate (P)	2.33	2.18	0.28	0.97	2.51
Potash (K)	1.86	1.84	0.19	1.52	2.47
Phosphate + potash (PK)	2.65	2.32	0.27	1.35	2.50

NUTRIENT COMPOSITION AND DEFICIENCY SYMPTOMS

The feeding value of hay depends partly on its mineral content. In this experiment the application of phosphate fertilizer increased the average phosphorus content of first-cutting hay by approximately 50

percent. A similar highly significant increase in potassium content resulted from topdressing with muriate of potash. The nitrogen content of fertilized hay was only slightly higher than that of hay which did not receive fertilizer.

On a number of the fields the alfalfa or clover from unfertilized plots or from plots which received only phosphate showed marked potassium deficiency symptoms. In some cases the deficiency symptoms were more intense on the plots fertilized with phosphate than on those which were untreated. This was probably due to the greater need for potassium by plants which had been stimulated by the phosphate fertilizer.

Phosphorus deficiency symptoms, except for depressed yields, did not occur. This was not surprising, however, since such symptoms are not so readily detected as are those of potassium deficiency. A previous publication[1] describes the symptoms of both deficiencies.

More and more persons are becoming familiar with the nature of the various hunger signs when certain nutrients are unavailable to crops. Such symptoms are good evidence that additional nutrients are required. Whether supplemental fertilizers applied to a field crop in the same season will be profitable depends on several factors including stage of plant growth and weather conditions.

SOIL TEST—CROP RESPONSE CORRELATION

When the fields are divided on the basis of significant yield increase due to topdressing, as in Table 2, the average soil tests according to the Spurway reserve method[2] were 28 and 35 pounds respectively for the high- and low-response groups. The difference is not large, and the correlation between soil tests for either phosphorus or potassium and yield response to fertilizer is low and not of a significant nature. This suggests that soil tests may not be entirely satisfactory as a sole means of soil fertility diagnosis. Such tests have definite limitations when they are used to predict the adequacy with which soil nutrients can be supplied to field crops. This is especially true in the case of the element nitrogen. By using critical nutrient levels established in 1946 it was found possible to estimate 1947 response to phosphorus fertilizers with an accuracy of 80 percent and response to potash with an accuracy of 65 percent.

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[1]Michigan Agr. Exp. Sta. Spec. Bull. 353. 1949.
[2]Michigan Agr. Exp. Sta. Tech. Bull. 132. 1949.

TABLE 2—A comparison between hay yields and soil tests for phosphorus and potassium on responding and non-responding fields in 1946

Number of fields tested	Average yield increase over check, tons/acre	Soil test value for P or K, pounds/acre	Correlation coefficient soil test vs. yield response to fertilizer
	Phosphate comparison		
58 responding	0.94	28	−0.22
8 non-responding	0.07	35	.....
	Potash comparison		
43 responding	1.02	102	−0.25
23 non-responding	0.10	115	.....

TISSUE TEST—CROP RESPONSE CORRELATION

In Tables 3 and 4 are presented data to show a comparison between plant tissue and soil tests and yield response of legume hay to fertilizers. In the case of phosphorus, tissue tests were more closely related to crop response than were soil tests. In only two out of thirty-seven fields in which the phosphorus tissue test was low, did the hay fail to respond significantly to phosphate fertilizer, while one-third of the fields in which the tests were high or very high did not respond. Furthermore, the yield increase from the fields in which the tissue test was high were very small, even though some of the differences were significant.

With potash, soil and plant tissue tests agreed rather closely. The average soil test value for hay having low-potash tissue tests was 96 pounds per acre as compared with 159 pounds per acre for the high-potash tissue test group. Both tests seemed to correlate fairly well

TABLE 3—A comparison between plant tissue and soil tests for phosphorus and respons of hay to phosphate fertilizer

Phosphorus level in fresh plant tissue	Average soil test level, pounds/acre	Average yield increase, tons/acre	Number of fields showing significant response	Number of fields showing no response
Very low and low	20	0.77	35	2
Medium	21	0.50	18	4
High and very high	43	0.18	6	3

TABLE 4—A comparison between plant tissue and soil tests for potassium and response of hay to potash fertilizer

Potash in tissue level	Average soil test level, pounds/acre	Average yield increase, tons/acre	Number of fields showing significant response	Number of fields showing no response
Very low to low.....	96	0.39	28	5
Medium low to medium high.....	104	0.04	8	10
High to very high.....	159	0.12	5	10

with crop response. In the low-potash tissue test group, only five of thirty-three soils fell into the no response group, while in the high-testing group, the corresponding number was 10 out of 15. Again, the increase in yield was very small in the high-potash tissue test group. In this respect, the situation was the same for potassium as for phosphorus.

TISSUE TEST—ASH ANALYSIS CORRELATION

A very direct relationship exists between tissue tests and the total nutrients in hay from all treatments. The summarization of over 180 individual tissue and ash analyses in Table 5 reveals that there is a regular increase in the percentage of total phosphorus and potassium as the tissue test level rises. In comparing high and low tissue test levels, this significant increase in the case of phosphorus amounted to about 50 percent. The potassium content of hay samples having high-potash tissue tests was over twice as great as at the low level. It is of interest that all of the plots that received no phosphate fertilizer were in the low tissue test grouping, while 90 percent of the plots receiving

TABLE 5—The relationship between tissue tests and ash analysis for phosphorus and potassium in legume hay

Nutrient level in fresh plant tissue	Phosphorus tests		Potassium tests	
	Number of plots tested	P in dry tissue, percent	Number of plots tested	K in dry tissue, percent
Very low to low.....	85	0.18	88	0.80
Medium low to medium high.....	38	0.21	43	1.12
High to very high.....	72	0.28	53	1.80

TABLE 6—Relation between potassium deficiency symptoms of legume hay and several soil and plant characteristics

	Number of fields under investigation	Average yield increase from potash, tons/acre	Plant tissue test level	Average potassium content of hay, percent	Average test for available potassium, lb./acre
Deficiency symptoms evident	6	0.53	low	0.50	71
Deficiency symptoms not present	25	0.02	7 low 8 medium 10 high	1.19	124

no potash fertilizer also fell in this same category. In contrast, in the high tissue test group, 77 and 68 percent of the hay samples from plots treated with phosphate and potash, respectively, fell into the high tissue test grouping.

Ash analysis as a diagnostic aid must be confined to research studies of the effect of various factors on plant growth. Since such tests are time-consuming and must be conducted in the laboratory, they have little value in helping the farmer, field man, or county agricultural agent in diagnosing the nutrient requirements of crops. The close relationship between tissue tests and ash analyses indicates that the rapid tissue tests will be used to a greater extent in the future. However, to obtain maximum benefits from tissue tests, they must be made several times, especially during the first half of the growing season. In this way possible plant food requirements can be noted even before deficiency symptoms appear in the crop.

The results from six hay fields showing definite hunger signs for potash are compared in Table 6 with those from 25 non-responding locations. Distinct differences are evident between the average soil test for available potassium, the potassium tissue test, the total potassium in the hay, and the average yield increase from applied potash fertilizer.

It is evident the best program for diagnosis of chemical problems in soil fertility requires the integrated use of the various diagnostic techniques discussed.

JOURNAL ARTICLE ABSTRACTS

How Much Support Can Co-ops Count On?

GIBSON, D. L.

News for Farmer Cooperatives, Nov. 1948:8-9, 15-16 (Journal Article 994 from the Michigan Agricultural Experiment Station)

Farmer opinion about farm cooperatives was studied by interviewing 500 farmers, both members and non-members of cooperatives, in five selected areas of Michigan. Opinion about cooperatives in general was very high. Usually, however, farmers tended to think of cooperatives as advantageous because of the possibility of immediate economic gain rather than from any long-time economic investment. Moreover, about a third of the members appeared to be only "fair weather" friends who would desert their organization if it occasionally got in a position where it could not meet competition. The most common source of information about co-ops, for both members and non-members, was conversation with the managers and employees who operate the co-op.

Riboflavin, Nitrogen and Thiamine Metabolism of Women with Active Tuberculosis

BREWER, W. D.; TOBEY, H. L.; KAN, D. H. P.; OHLSON, M. A., AND STRINGER, C. J.

Jour. Am. Dietetic Assoc. 26(11):861. 1950 (Journal Article 1060 from the Michigan Agricultural Experiment Station)

The riboflavin, nitrogen and thiamine metabolism of six women with moderately advanced, active tuberculosis was studied. The subjects were non-ambulatory patients of the county sanatorium, and the regular hospital diet was served throughout the experiment. The riboflavin and nitrogen contents of the diets were varied by adjustment of the milk intake. During periods 1 and 2, the milk intake was restricted to 300 grams daily, and for periods 3 and 4, the intake was increased to 1,200 grams per day. Daily supplements of 5 mg. riboflavin were given during periods 2 and 4. Fourteen days of dietary adjustment preceded each 7-day balance period during which the intakes and excretions of nitrogen, riboflavin and thiamine were determined. The urinary excretion of riboflavin and thiamine following a test dose of 3 mg. riboflavin and 3 mg. thiamine was measured on the last day of each balance period.

The average daily intakes of riboflavin for the four periods were 1.35, 6.41, 2.60 and 7.79 mg. The average daily excretions were 0.31, 3.53, 1.08 and 5.63 mg. riboflavin, respectively. The urinary excretion of riboflavin varied inversely with nitrogen retention. The retentions of nitrogen by the tuberculous women were similar to those of healthy women at comparable intakes. All of the subjects were in nitrogen equilibrium or retaining nitrogen at intakes above 10 grams daily.

The urinary excretion of riboflavin and thiamine by the tuberculous women was similar to that of healthy young women at similar intakes.

A Comparative Study of Media for the Detection of Streptococci in Water and Sewage.

MALLMANN, W. L., AND SELIGMANN, E. B.

Am. Jour. Pub. Health 40:286-289. 1950 (Journal Article 1100 from the Michigan Agricultural Experiment Station)

A new medium, dextrose azide (Rothe), is presented, and it is a selective one for the growth of streptococci. The medium consists of tryptose (Difco) 1.5 percent, beef extract (Difco) 0.45 percent, dextrose 0.75 percent, sodium chloride 0.75 percent, and sodium azide 0.02 percent. The medium is adjusted to a pH of 7.2. It was found to be superior quantitatively to lactose broth, azide broth (Mallmann) and S. F. broth (Hajna and Perry).

The Present Status of Cycloheximide (Acti-dione) as a Fungicide

VAUGHN, J. R., AND HAMNER, C. L.

Proc. Am. Soc. Hort. Sci. 54:435-437. 1950 (Journal Article 1112 from the Michigan Agricultural Experiment Station)

The antibiotic material cycloheximide (trade name Acti-dione) is one of the chemicals produced by the growth of *Streptomycis griseus.* Unlike streptomycin, cycloheximide is not actively antibiotic against bacteria but is active against many fungi. Ten different fungi were grown on potato dextrose agar in petri dishes. There were five series of these plates containing 0, 0.2, 1, 2, 4 and 20 ppm. of cycloheximide. All 10 were strongly inhibited by 20 ppm. Greenhouse tests have been reported which show that the material gives satisfactory control of powdery mildew of beans and roses when sprayed with concentrations as low as 2, 3, and 4 ppm. Some preliminary work with turf diseases indicates that cycloheximide may have value as a turf fungicide. Tests made on several golf greens gave as good or better control of brown patch and dollar spot than the mercury compounds formerly used by greenskeepers.

The Selective Inhibition of the Growth of Green Plants and Fungi by Beta Methyl Umbelliferone

HAMNER, C. L.; SELL, H. M.; KLOMPARENS, WM., AND VAUGHN, J. R.

Botanical Gazette 112(1):135-137. 1950 (Journal Article 1164 from the Michigan Agricultural Experiment Station)

Beta methyl umbelliferone has been found effective in inhibiting the growth of certain green plants and fungi. This compound is a substituted coumarin and undergoes many of the reactions of this class of compound. The germination and growth of Red Kidney bean and cucumber seeds and seedlings were markedly inhibited, the degree of inhibition being in proportion to the concentration of the chemical. Besides its action on green plants, beta methyl umbelliferone has also been found to inhibit the growth of three pathogenic fungi.

Chemical Agents for the Sanitization of Food Utensils

MALLMANN, W. L.

Modern Sanitation 3(1):52. 1951 (Journal Article 1185 from the Michigan Agricultural Experiment Station)

A resumè of the work of the author and his associates on two types of sanitizing agents, the hypochlorites and quaternary ammonium compounds is presented. The material covers the behavior of the compounds under various conditions of use. Both types of compounds are reported to be satisfactory sanitizers when properly used. The author stresses the fact that surfaces must be free of organic and inorganic soil prior to sanitization.

Toxicity Studies on Alkyldimethylbenzylammonium Chloride in Rats and Dogs

ALFREDSON, B. V.; STIEFEL, J. R.; THORP, FRANK, JR.; BATEN, W. D., AND GRAY, M. L.

Jour. Am. Pharmaceutical Assoc. XL(6):263-267. 1951 (Journal Article 1192 from the Michigan Agricultural Experiment Station)

Results are presented concerning the effects of alkyldimethylbenzylammonium chloride when fed in the diets of rats and dogs and when given in single doses by stomach tube to rats. Rats were fed for a 2-year period in one experiment and for 4 months in another. Dogs were fed the test agent for 15 weeks. The results of these studies show no demonstrable evidence of toxicity for alkyldimethylbenzylammonium chloride when fed in concentrations of 0.25 percent or less in the diet of the rats and 0.12 percent or less in the diet of the dogs. The acute LD_{50} of this compound in rats, as determined by single oral dosages, was found to be 234.3 $\pm$ 26.5 mg./Kg. body weight.

Sanitation of Bulk Drink Vending Machines

MALLMANN, W. L., AND HARLEY, R. J.

Modern Sanitation 3(6):53. 1951 (Journal Article 1194 from the Michigan Agricultural Experiment Station)

A study of the sanitary aspects of carbonated beverages dispensed by means of a cup vending machine was made. The fountain syrups used were found to be self-sanitizing. The vending area protected by sliding doors and germicidal lamps was low in bacterial populations. The bacteria present initially in the finished drink decreased rapidly, owing to the bactericidal activity of the syrups.

Chemical Studies of Oats. II. The Relationship Between Avenin and Total Protein

FREY, K. J.

Cereal Chemistry 28:506-509. 1951 (Journal Article 1204 from the Michigan Agricultural Experiment Station)

A number of varieties of oats grown in 1947 and in 1949 were analyzed for total protein and avenin. Huron variety was the lowest and C. I. 5298 was the

highest in both total protein and avenin percentages. Other varieties with high protein percentage were Bonda and C. I. 3656. It was shown that the total protein of both high and low protein varieties contained about the same proportion of avenin. For all of the samples the avenin averaged 18 percent of the total protein.

New Objectives in Sugar Beet Breeding

KOHLS, HAROLD

Proc. Sixth Reg. Meeting Soc. Sug. Beet Tech. Eastern U. S. and Canada. 1951. pp. 59-63. (Journal Article 1217 from the Michigan Agricultural Experiment Station)

The main objectives in sugar beet breeding are to produce a variety that is high in tonnage and sugar content, very resistant to disease, particularly leaf spot and blackroot, resistant to cold, and round in shape. Hybrid 125 is the nearest to the ideal in the eastern sugar beet area. It has higher yielding ability and more resistance to blackroot than the commercial variety now in use. It is about equal to the commercial variety in sugar content and resistance to leaf spot, and no serious defects have appeared.

Chlorophyl Inhibition and Growth Regulation by Several Tetronic Acid Derivatives

ALAMERCERY, J.; HAMNER, C. L., AND LATUS, M.

Nature 168:85. July 14, 1951 (Journal Article 1218 from the Michigan Agricultural Experiment Station)

Several tetronic acid derivatives were tested on germinating seeds and seedlings of a marketed variety of cucumber and White Banner variety of wheat. The compound producing the most significant results was 3(α-imino-ethyl) 5-methyl-tetronic acid. When cucumber seeds were germinated and grown in 100 ppm. of this compound, they produced large yellow cotyledons and etiolated hypocotyls. When these seedlings were transplanted into soil and placed on a greenhouse bench, they became white, resembling albino plants and died after six days. The action of 2 imino-4-hydroxy-5-dephenyl oxazole was in sharp contrast to that of the preceding compound. When a young primary leaf of Red Kidney bean was dipped in a solution containing 1000 ppm. the expansion of the leaf was not only almost completely inhibited, but also the leaf became dark green.

Autoradiography as an Aid in Determining the Gross Absorption and Utilization of Foliar Applied Nutrients

WITTWER, S. H., AND LUNDAHL, W. S.

Plant Physiology 26(4):792-797. 1951 (Journal Article 1233 from the Michigan Agricultural Experiment Station)

Autoradiography offers a means of obtaining visual records of the absorption, translocation and selective mobilization of foliar applied nutrients. A method of simultaneously preparing a large number of autoradiograms by exposure of 8 x 10 inch Kodak No-Screen X-Ray film to properly prepared plant specimens is

described. Autoradiograms of bean, corn and tomato plants demonstrate that leaves are efficient organs for absorption of radio-phosphorus. Subsequent distribution in the bean plant of the foliar applied radionuclide is comparable to that taken up by roots. The relatively greater nutrient absorption efficiency of the younger expanding leaves is demonstrated.

Methodology in a Michigan Health Survey

HOFFER, CHARLES R., AND GIBSON, DUANE L.

Rural Sociology 16(2):164-168. 1951 (Journal Article 1236 from the Michigan Agricultural Experiment Station)

The article summarizes the development of the "symptoms approach" as a method of measuring unmet medical needs, describes the origin and purpose of the state-wide health study, and presents data to indicate that when the female head of the family is used as the sole source of information on family health, the "symptoms approach" instrument for measuring unmet medical needs will produce an 8-percent under-enumeration of the need which other adults in the family have for medical care. The article also describes the sampling procedure used in the study, the methods used in the selection and training of interviewers and discusses briefly the policy of continuous "involvement" of the sponsoring agency which was used by the research project committee.

Chlorophyll Inhibition and Herbicidal Action of 3-(A-Imino-Ethyl) 5-Methyl Tetronic Acid

HAMNER, C. L., AND TUKEY, H. B.

Botanical Gazette 112(4):525-528. 1951 (Journal Article 1240 from the Michigan Agricultural Experiment Station)

3-(Alpha-imino-ethyl) 5-methyl tetronic acid inhibits chlorophyll formations in plants. General plant development is suppressed, but otherwise no anomalous growth or formative effects are apparent. Food reserves are depleted, and the plant is exhausted and dies. Because of the peculiar nature of its action the chemical may have value as a herbicide. No known herbicide is effective in completely killing deep-rooted perennials. The compound is of special interest also because it appears to be extremely effective on monocotyledonous plants.

A Comparative Bacteriological Study of Bulk Milk vs. Bottled Milk

MALLMANN, W. L., AND LAUG, M. C.

Modern Sanitation 3(11):61. 1951 (Journal Article 1247 from the Michigan Agricultural Experiment Station)

Two bulk milk dispensing units in commercial use were compared with bottled milk. In each test, homogenized milk of the same batch was used. The results indicated that if the dispenser cans are not properly cleaned and sanitized the product will be of higher bacterial count than that in bottles. If properly cleaned and sanitized, a dispenser can, with the least possible number of avenues of contamination, yield a product equal to that of bottled milk.

The Riboflavin Content of Fresh and Stored Shell Eggs

EVANS, ROBERT JOHN; BUTTS, HELEN A., AND DAVIDSON, J. A.

Poultry Sc. 31(2):269-273. 1952 (Journal Article 1254 from the Michigan Agricultural Experiment Station)

Eggs were obtained from eight hens that were kept in laying cages and fed a diet of constant composition. Three eggs from each hen were used for each riboflavin assay. Eggs were assayed fresh and after 3, 6, and 12 months' storage at 0° C. Fresh eggs contained on the average 169.7 μg. of riboflavin per egg (3.49 μg. per gm.) of which 100.6 μg. was in the white (3.14 μg. per gm.) and 69.1 μg. was in the yolk (4.15 μg. per gm.). During the first 6 months of storage, 14.1 percent of the riboflavin was lost. No further loss occurred during the next 6 months, but there was a transfer of riboflavin from the yolk to the white. Twelve-month-old eggs contained 147.0 μg. of riboflavin per egg (3.07 μg. per gm.) of which 92.7 μg. was in the white (3.33 μg. per gm.) and 54.3 μg. in the yolk (2.72 μg. per gm.).

Diffusion Characteristics of 1-3 Dichloropropene and 1-2 Dibromoethane in Soils

SIEGEL, J. J.; ERICKSON, A. E., AND TURK, L. M.

Soil Science 72(5):333-340. 1951 (Journal Article 1255 from the Michigan Agricultural Experiment Station)

The diffusion characteristics of 1-3 dichloropropene and 1-2 dibromoethane in soils were studied by sorption isotherms and radioactive tracer techniques.

There are indications that the extent of diffusion of 1-3 dichloropropene and 1-2 dibromoethane is approximately equal in identical soils at the same moisture level. There is little if any penetration of the compounds into the soil mass above the point of injection if the soils are allowed to remain undisturbed after treatment. The dispersion is lateral and downward from the point of injection, with the greatest concentrations of the compounds localized around a vertical axis through the point of injection.

There is evidence that the compounds are sorbed by soils and that this sorption is primarily due to the colloidal organic matter. Thus, diffusion of the compounds through soils is greatly affected by the amount of organic matter present.

Optimum diffusion was obtained with the soils at the moisture equivalent. Saturation of the soil decreased the extent of vertical diffusion, and air-drying resulted in least extensive dispersion in all directions.

A Study of Urease Activity in Cells of the Genus Brucella

SANDERS, EVELYN, AND WARNER, JUANITA

Jour. Bacteriology 62(5):591-598. 1951 (Journal Article 1263 from the Michigan Agricultural Experiment Station)

A titrimetric method is described for quantitative determination of urease activity in cells of the genus *Brucella*. Sixty-seven culture of *Brucella* were examined; 50 of those examined were pure colonial type cultures.

This study resulted in the classification of the cultures of *Brucella* into two distinct groups: a) urease activity 1.9 to 4.0, all strains (13) of *Brucella suis* and

approximately one-third (14) of the cultures of *Brucella melitensis;* and b) urease activity 0.1 to 0.7, all strains (11) of *Brucella abortus* and the remaining two-thirds (29) of the cultures of *Br. melitensis.* The wide range of urease activity within the species *Br. melitensis* was detected by each of three colorimetric methods.

Urease activity was not a characteristic property of the colonial growth types of the *Brucella* examined. A measurement of urease activity of the cells cannot be used as an aid in differentiation of the three species of *Brucella.*

Nutritive Values of Crops and Cows' Milk as Affected by Soil Fertility. II. The Essential Amino Acids in Colostrum and Milk Proteins

DUNCAN, C. W.; WATSON, Gertrude I., DUNN, K. M., AND ELY, R. E.

Jour. Dairy Sci. 35(2):128-139. 1952 (Journal Article 1269 from the Michigan Agricultural Experiment Station)

The essential amino acids in colostrum and milk proteins of cows maintained on feeds grown on highly fertilized and on highly depleted soil of the same type have been determined. There was no essential difference between the amino acid pattern of the "first" colostrum and that obtained 24 hour postpartum when the values are expressed as percent of the crude protein, except that the arginine content was higher in the colostrum secreted by the cows receiving the unfertilized feed. The amount of crude protein in colostrum declined approximately 50-percent with 24-hour postpartum. The genetic differences between cows would appear to be greater than differences between groups.

The amino acid concentrations of the 60-day composite milk samples obtained from each group of cows varied less than ±10 percent, except that the methionine content of the milk produced by the cows receiving the unfertilized feeds was 12 percent higher than that produced by the cows receiving the fertilized feeds. The average amount of total crude protein in the milk was almost identical in both groups. Individual cow differences were larger than group differences.

The average amino acid values in the terminal milk proteins from each group of cows deviated less than ±10 percent, except that the leucine content of the milk produced by the cows receiving the unfertilized feeds was consistently higher than that produced by the cows receiving the fertilized feeds. The average total protein content in the milk produced by both groups was approximately the same.

The amounts of isoleucine and methionine increased as lactation progressed, whereas arginine and tryptophan decreased progressively from colostrum to terminal milk. Threonine decreased markedly during the first 60 days postpartum and then increased slightly as lactation progressed. The other amino acids were relatively unchanged.

The concepts that badly depleted soils produce crops of lower nutritive value than highly fertilized soils or that commercial fertilizers decrease the nutritive properties of crops are not confirmed by this investigation. Insofar as the amino acid composition of milk proteins is concerned, evidence is lacking which indicates that the nutritive value of feeds is dependent chiefly on soil fertility.

The Effect of Preharvest Foliar Sprays of Maleic Hydrazide on Sprout Inhibition and Storage Quality of Potatoes

PATERSON, D. P.; WITTWER, S. H.; WELLER, L. E., AND SELL, H. M.

Plant Phys. 27(1):135-142. 1952 (Journal Article 1270 from the Michigan Agricultural Experiment Station)

Sprays of 500, 1000 and 2500 ppm. of maleic hydrazide applied to the foliage of Irish Cobbler and Pontiac potato vines approximately 1 to 7 weeks prior to harvest were effective in prolonging dormancy of tubers held in storage for 7 months at temperatures of 45 and 55°F. The inhibition of sprouting resulting from single preharvest was more complete than was obtained with preharvest foliar treatments of 2,4,5-trichlorophenoxyacetic acid or with postharvest applications of the methyl ester of alpha-naphthaleneacetic acid. Maleic hydrazide induced sprout inhibition treatments were accompanied by an absence of shriveling with little or no deterioration of quality and with no reduction of yield of U. S. No. 1 potatoes. Apical dominance of both tubers and individual sprouts on the tubers was destroyed. The percentages of reducing and non-reducing sugars were lower in maleic hydrazide treated potatoes stored at 45° F. The lower content of reducing sugar was evidenced in lighter colored chips. The possible significance of maleic hydrazide for controlling the degradation of starch to sugar in the storage of potatoes at low temperatures as well as the inhibition of sprouting at high temperatures is discussed.

Unidentified Dietary Factors in Dairy Cattle Nutrition. I. Digestibility of Peanut Hulls and Their Use in "Ballast" Studies with Milking Cows Depleted on Hay Alone

HUFFMAN, C. F., AND DUNCAN, C. W.

Jour. Dairy Sci. 35:30-40. 1952 (Journal Article 1273 from the Michigan Agricultural Experiment Station)

Four depleted, milking Holstein cows were used to determine the digestibility of hay when fed alone and after 15 pounds of the hay had been replaced with 6 pounds of corn and 9 pounds of peanut hulls. Four Holstein cows were maintained on the basal hay ration throughout the experiment as controls.

The coefficients of digestibility of the peanut hulls were found to be: dry matter, 21.1; organic matter, 21.1; carbohydrates, 20.9; protein, 23.7; ether extract, 13.0; crude fiber, 24.0; and nitrogen-free extract, 10.5. The "ballast" values were calculated to be: undigested dry matter, 78.9; undigested organic matter, 78.9; and undigested carbohydrates, 79.4 percent.

Three of four cows increased in the production of F. C. M. when changed from hay alone to a hay-corn-peanut hulls ration, whereas all of the control cows declined in F. C. M. All of the cows increased in the number of pounds of F. C. M. per 100 pounds of T. D. N. on the hay-corn-peanut hulls ration, while all of the control cows showed a decline. The amount of F. C. M. increased appreciably in spite of the fact that the calculated net-energy and starch equivalent values declined markedly and the crude fiber and undigested carbohydrates increased.

The results of this investigation support the modern concept of a balanced ration and illustrate some of the imperfections in both the calculated net-energy and the starch equivalent concepts as scientific methods of feed evaluation. The data presented in this paper give further support to a contention that grain supplies the unidentified factor(s) needed by some hays for more efficient milk production. Undigested carbohydrates appear to be a better index for "ballast" evaluations than either undigested dry matter or undigested organic matter. The losses in body weight of the cows of the hay-corn-peanut hulls ration appeared to be due to a decrease in wet fecal weights due to a lack of fill, although the daily amount of fecal dry matter increased.

Unidentified Dietary Factors in Dairy Cattle Nutrition. II. Further Evidence of an Unidentified Factor(s) in Grain Needed to Balance Roughage for Milk Production

HUFFMAN, C. F.; DUNCAN, C. W., AND CHANCE, C. M.

Jour. Dairy Sci. 35:41-50. 1952 (Journal Article 1274 from the Michigan Agricultural Experiment Station)

Seventeen milking cows, which had been depleted of unidentified lactation factor(s) on a ration of hay alone, were used in 25 trials to determine the effect of replacing part of the hay with grain and either wheat straw, wood meal (oak) or peanut hulls. The basal periods varied from 9 to 18 days and the supplemental periods ranged from 9 to 27 days. In all but one trial, the replacement of part of the hay with these feed stuffs resulted in an increase in 4 percent fat-corrected milk, even though the intake of total digestible nutrients, calculated net-energy and starch equivalent decreased and the crude fiber in the dry matter and ballast (undigested organic matter) increased. Crude fiber values up to 38 percent of the dry matter did not depress milk production when the cows were changed from hay alone to a ration of hay, corn and peanut hulls. The results show that calculated net-energy and starch equivalent values of individual feeds are not additive but support the modern concept of balanced ration. Further evidence is presented to show that the unidentified lactation factor(s) in grain is needed to balance roughages.

An Improved Synthesis of 3-Acetimido-5-Methyltetronic Acid

REBSTOCK, THEODORE L., AND SELL, HAROLD M.

Jour. Am. Chem. Soc. 74:274. 1952 (Journal Article 1275 from the Michigan Agricultural Experiment Station)

A modification of Lecocq's method for the synthesis of 3-acetimido-5-methyltetronic acid is described by reacting Ethyl-β-amino crotonate with α-bromopropionyl bromide. The total yield is 30 percent of the theoretical.

Use of Surital Sodium and Curare in Small Animal Surgery

BRINKER, W. O.

North Am. Vet. 32:832-834. 1951 (Journal Article 1279 from the Michigan Agricultural Experiment Station)

The results and observations on the clinical use of Surital and Curare as an intravenous anesthetic in 72 small animal cases was reported. The mixture used was composed of one gram of Surital Sodium, 22.6 cc. sterile physiological saline and 2.4 cc. of d-Tubocurarine chloride. The approximate dosage was one cc. per five pounds of bodyweight, however, in all cases the solution was injected slowly until the desired degree of anesthesia was obtained. Surgical cases included fractures, neoplasms, cataracts, pyometras, dislocations, urethral and cystic calculi, perineal hernias, Caesarian section, extraction of teeth, x-ray therapy and removal of foreign bodies. Results of clinical use indicate that it is short acting, that induction and post operative excitement is practically nil, and that it produces maximum relaxation and has a relatively high margin of safety if given slowly to effect.

Temperature Adaptation in the Baby Pig

Newland, H. W.; McMillen, W. N., and Reineke, E. P.

Jour. Animal Sci. 11(1):118-133. 1952 (Journal Article 1280 from the Michigan Agricultural Experiment Station)

The biological effects of chilling on new-born pigs were studied, using pigs from the Michigan State College swine herd. Body temperatures of pigs were taken at birth and at frequent intervals up to 10 days old, and comparisons were made under warm and cold environments. Blood hematocrit and glucose changes were observed under the two environmental conditions. The body temperature regulating mechanism was found to be underdeveloped in the baby pig; normal body temperature of 102.5° F. not being reached until 2 and 10 days of age in environments to 65° to 75° F. and 25° to 35° F. respectively. Pigs 24 hours old withstood a temperature of 34° F. with less drop in body temperature than pigs under 4 hours old. There was a significant correlation between the weight of a pig and its ability to adapt itself to its environment. Chilling 2-day-old pigs caused the blood hematocrit to decrease. There was an increase in blood sugar when 1-day-old pigs were chilled at 34° F. Pigs fasted 8 hours before chilling showed less glucose increase than those fasted 3 and 5 hours.

Counteraction of Cortisone Inhibition of Body, Hair, and Thymus Growth by Vitamin B_{12} and Aureomycin

Meites, Joseph

Proc. Soc. Experimental Biology and Medicine 78:692-695. 1951 (Journal Article 1286 from the Michigan Agricultural Experiment Station)

1) Cortisone was injected in daily doses of 0.5 mg. for 30 days into 130 immature male albino rats on a Vitamin B_{12}-deficient diet. The depressions of body, hair, and thymus growth which resulted were completely or partially prevented by incorporating 200 μg. of Vitamin B_{12} per kilo of ration or 0.005 percent aureomycin. 2) Vitamin B_{12} was more effective in these respects than aureomycin, and the combination of the two substances was more effective than either alone. 3) The favorable actions of the vitamin and antibiotic were accompanied by an increase in food consumption and greater efficiency in converting food into body weight gains. 4) It is concluded that when large doses of cortisone are injected into rats on a Vitamin B_{12}-deficient diet, the deficiency becomes aggravated and thus accounts at least in part for the observed inhibitions of body and hair growth. The mechanisms by which Vitamin B_{12} and aureomycin protect the thymus against cortisone action are as yet unknown.

Weight Reduction on Low Fat and Low Carbohydrate Diet. I. Clinical Results and Energy Metabolism

Cederquist, D. C.; Brewer, W. D.; Beegle, R. M.; Wagoner, A. N.; Dunsing, D., and Ohlson, M. A.

Jour. Am. Diet. Assoc. 28(2):113-116. 1952 (Journal Article 1290 from the Michigan Agricultural Experiment Station)

Data are reported for two groups of overweight college age women who were maintained on low fat or low carbohydrate reducing diets. The low fat diet

furnished approximately 1,200 calories and 11 grams of nitrogen per day. Weight losses in three out of four cases were unsatisfactory. The estimated daily energy expenditures as calculated from the basal metabolism records and activity records showed a decrease in energy expenditure of 200-500 calories a day; this decrease may account for a part of the failure in weight loss. The subjects reported a feeling of lassitude and hunger between meals.

The low carbohydrate diet furnished approximately 1,500 calories a day and 16 grams of nitrogen. More than half of the ingested calories were derived from fat. Weight losses ranged from 8.8 to 16.8 kilograms in the 16-week experimental period. Estimations of daily energy expenditures indicated a decrease of 45 to 340 calories for six subjects and an increase of 350 calories for one subject. The subjects reported a feeling of well-being and satisfaction. Hunger between meals was not a problem.

The data presented constitutes a progress report of work completed to date.

Marked Changes in Hormone Levels and Nutritional Requirements

MEITES, JOSEPH

Metabolism 1(1):58-67. 1952 (Journal Article 1293 from the Michigan Agricultural Experiment Station)

Large doses of diethylstilbestrol or thyroprotein, fed to young male rats on an adequate ration, severely inhibited body growth. Supplementation of the ration with Vitamin B_{12} partially counteracted growth inhibition and increased appetite. The decrease in testes weight which resulted from the hyperestrinism or hyperthyroidism, and the increase in weight of the seminal vesicles by the estrogen, were not influenced by Vitamin B_{12}.

The inhibition of body growth in young female rats by thyroprotein was completely counteracted by incorporation of small amounts of procaine penicillin G or neomycin sulfate in an otherwise adequate diet. Streptomycin sulfate was ineffective in this respect. The large increase in basal oxygen consumption (74 percent) induced by thyroprotein was not affected by the antibiotics.

Of 18 young male rats on a Vitamin B_{12}-deficient ration subjected to thyroparathyroidectomy, 15 survived for 30 days, 5 for 60 days, and none for 90 days. When the diet was supplemented with Vitamin B_{12}, 21 out of 26 survived for 30 days, 19 survived for 60 days, 17 for 90 days, and 16 for 120 days. The vitamin enabled growth to proceed in the surviving rats, although at a considerably slower rate than in intact rats given Vitamin B_{12}.

Large daily injections of cortisone inhibited body and hair growth in young male rats fed a ration deficient in Vitamin B_{12}. The addition of Vitamin B_{12}, either alone or together with aureomycin hydrochloride, to the diet completely counteracted inhibition of body growth and partially of hair growth. The vitamin and antibiotic completely protected the thymus against atrophy by cortisone but did not prevent the decrease in adrenal weight.

It is concluded that a) marked changes in thyroid, estrogen, or cortisone levels in the body can increase requirements for Vitamin B_{12} and possibly other dietary factors in rats; b) supplementation of diets with Vitamin B_{12} and antibiotics can partially or completely prevent manifestations of dietary deficiencies induced by these hormones; and c) Vitamin B_{12} and the antibiotics do not alter certain characteristic actions of these hormones in the body, with the exception that cortisone-induced atrophy of the thymus can be prevented by Vitamin B_{12} and aureomycin.

A Report on the Presence of Renal Coccidiosis in Michigan

LINDQUIST, WILLIAM D.; BELDING, RALPH C., AND HITCHCOCK, DOROTHY J.

M.S.C. Vet. 12(1):19-20. 1951 (Journal Article 1294 from the Michigan Agricultural Experiment Station)

A report was made on two separate outbreaks of renal coccidiosis in Michigan with the attendant clinical picture. Oocysts from the macerated kidneys were sporulated in 96 hours and fed to experimental birds with control birds left for comparison. Failure to produce a laboratory infection was attributed to too few oocysts in a sporulated condition. Further experimentation awaits more material.

Bovine Spermatozoa as Revealed by Electron Microscopy

STOCKTON, JACK J., AND GEBHARD, WILLIAM H.

M.S.C. Vet. 12(2):99-101. 1952 (Journal Article 1321 from the Michigan Agricultural Experiment Station)

Electron micrographs of the head, neck, centrol portion of the tail and the terminal portion of the tail of bovine spermatozoa are presented. A method for preparing a bovine semen sample for electron microscopy is given.

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